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**MBA PROFESSIONAL REPORT**

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# AN ANALYSIS OF THE U.S. ARMY'S T-11 ADVANCED TACTICAL PARACHUTE SYSTEM AND POTENTIAL PATH FORWARD

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**December 2016**


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Since the fielding of the T-11 Advanced Tactical Parachute System (ATPS) in 2009, nine paratroopers have died utilizing this parachute and its reserve, causing several senior military officials to question the design, safety, and effectiveness of the new parachute system. Several tests and studies were commissioned in response, subsequently concluding that the T-11 parachute has a reduced number of paratrooper jump-related injuries compared to the legacy T-10 parachute. Despite these findings, leaders within the Army Airborne community have requested continued assessments, modifications, and even a new parachute. The T-11 ATPS has been fully fielded, reaching full operational capability (FOC) in 2014. Using a case study approach, this report reviews the user community’s request to assess, modify, or develop a new parachute against potential acquisition approaches. To inform the recommendation, data is collected from stakeholders, and the advantages and disadvantages of acquisition approaches are compared and analyzed. This report concluded that one acquisition approach cannot address all of the issues and concerns identified by the airborne community and recommended that a combination of approaches be used for the T-11 ATPS program path forward.

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**AN ANALYSIS OF THE U.S. ARMY'S T-11 ADVANCED TACTICAL PARACHUTE SYSTEM AND POTENTIAL PATH FORWARD**

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Submitted in partial fulfillment of the requirements for the degree of

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## ABSTRACT

Since the fielding of the T-11 Advanced Tactical Parachute System (ATPS) in 2009, nine paratroopers have died utilizing this parachute and its reserve, causing several senior military officials to question the design, safety, and effectiveness of the new parachute system. Several tests and studies were commissioned in response, subsequently concluding that the T-11 parachute has a reduced number of paratrooper jump-related injuries compared to the legacy T-10 parachute. Despite these findings, leaders within the Army Airborne community have requested continued assessments, modifications, and even a new parachute. The T-11 ATPS has been fully fielded, reaching full operational capability (FOC) in 2014. Using a case study approach, this report reviews the user community's request to assess, modify, or develop a new parachute against potential acquisition approaches. To inform the recommendation, data is collected from stakeholders, and the advantages and disadvantages of acquisition approaches are compared and analyzed. This report concluded that one acquisition approach cannot address all of the issues and concerns identified by the airborne community and recommended that a combination of approaches be used for the T-11 ATPS program path forward.

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| | |
|---|---|
| AAB | Army Airborne Board |
| AAD | Automatic Activation Device |
| AAO | Army Authorization Objective |
| ABC | Airborne Corps |
| ABD | Airborne Division |
| ACAT | Acquisition Category |
| ADD | Aerial Delivery Directorate |
| AF | Accordion Fold |
| AGL | Above Ground Level |
| AK | Alaska |
| AOA | Analysis of Alternatives |
| AOD | Automatic Opening Device |
| APA | Additional Performance Attributes |
| APB | Acquisition Program Baseline |
| APdM | Assistant Product Manager |
| ARCIC | Army Capabilities Integration Center |
| ARCT | Airborne Regimental Combat Team |
| ARHS | Advanced Reserve Harness System |
| ARPHS | Advanced Reserve Parachute Harness System |
| ATPS | Advanced Tactical Parachute System |
| AWG | Airborne Working Group |
| BAC | Basic Airborne Course |
| BES | Budget Estimate Submission |
| C | Cargo |
| CA | California |
| CASA | Construcciones Aeronáuticas SA |
| CBA | Capabilities Based Assessment |
| CDD | Capabilities Development Document |

| | |
|---|---|
| CDID | Capabilities Development and Integration Directorate |
| CDR | Critical Design Review |
| CDS | Containerized Deployment System |
| CG | Commanding General |
| CH | Cargo Helicopter |
| CJCS | Chairman of the Joint Chiefs of Staff |
| CO | Colorado |
| COEA | Cost Operational Effectiveness Analysis |
| COL | Colonel |
| CPD | Capabilities Production Document |
| CRG | Collapsible Ripcord Grip |
| CRSC | Combat Readiness Safety Center |
| DA | Department of the Army |
| DAG | Defense Acquisition Guidebook |
| DAS | Defense Acquisition System |
| DC | Douglas Company |
| DOD | Department of Defense |
| DODD | Department of Defense Directive |
| DODI | Department of Defense Instruction |
| DOTMLPF-P | Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities, and Policy |
| DPG | Defense Planning Guidance |
| DT | Developmental Testing |
| DT&E | Developmental Test & Evaluation |
| DVT | Design Validation Testing |
| EMD | Engineering, Manufacturing, and Development |
| EOA | Early Operational Assessment |
| FM | Field Manual |
| FOC | Full Operational Capability |
| FOT&E | Follow-on Operational Test & Evaluation |

| | |
|---|---|
| Fps | Feet per second |
| FRP | Full Rate Production |
| FRPDR | Full Rate Production Decision Review |
| FUE | First Unit Equipped |
| GA | Georgia |
| HQDA | Headquarters Department of the Army |
| HSI | Human Systems Integration |
| ICD | Initial Capabilities Document |
| IOT&E | Initial Operational Test & Evaluation |
| JCIDS | Joint Capabilities Integration Development System |
| JMPI | Jumpmaster Personnel Inspection |
| JROC | Joint Requirements Oversight Council |
| JRTC | Joint Readiness Training Center |
| JWG | Joint Working Group |
| kias | Knots indicated air speed |
| KPP | Key Performance Parameter |
| KSA | Key System Attribute |
| L | Lumbar |
| LA | Louisiana |
| LALO | Low Altitude Low Opening |
| lbs | Pounds |
| LCC | Life-Cycle Cost |
| LCCE | Life Cycle Cost Estimate |
| LCSP | Life-Cycle Sustainment Plan |
| LFT&E | Live Fire Test and Evaluation |
| LRIP | Low Rate Initial Production |
| LTG | Lieutenant General |
| MAJ | Major |
| MC | Maneuverable Canopy |
| MCoE | Maneuver Center of Excellence |

| | |
|---|---|
| MDA | Milestone Decision Authority |
| MDAP | Major Defense Acquisition Program |
| MDD | Materiel Development Decision |
| MFF | Military Free Fall |
| MNS | Mission Needs Statement |
| MOS | Military Occupational Specialty |
| MRE | Meals Ready to Eat |
| MS | Milestone |
| MSA | Materiel Solution Analysis |
| MSL | Mean Sea Level |
| MWO | Modification Work Order |
| NC | North Carolina |
| NDI | Non-Developmental Item |
| NR | Net Ready |
| NSRDEC | Natick Soldier Research, Development, and Engineering Center |
| NSS | National Security Strategy |
| O&S | Operations and Support |
| ORD | Operational Requirements Document |
| OSS | Office of Strategic Services |
| OT | Operational Test |
| OT&E | Operational Test and Evaluation |
| P3I | Pre-Planned Product Improvement |
| PAS | Personnel Airdrop System |
| PdM | Product Manager |
| PDR | Preliminary Design Review |
| PEO | Program Executive Office |
| PIB | Parachute Infantry Battalion |
| POM | Program Objective Memorandum |
| POR | Program of Record |
| PPBE | Planning, Programming, Budget, and Execution |

| | |
|---|---|
| QMS | Quartermaster School |
| R | Reserve |
| RA | Ram Air |
| RFP | Request for Proposal |
| ROD | Rate of Descent |
| S&T | Science and Technology |
| SCIE | Soldier, Clothing, Individual Equipment |
| SF | Special Forces |
| SME | Subject Matter Expert |
| SOF | Special Operations Forces |
| SOFTAPS | Special Operation Forces Tactical Advanced Parachute System |
| SOUM | Safety of Use Message |
| SSB | Soldier Systems Branch |
| T | Troop |
| TC | Type Classification |
| TCC | Troop Carrier Command |
| TCM | Training and Doctrine Capabilities Manager |
| TD | Technology Development |
| TEMP | Test and Evaluation Master Plan |
| TM | Technical Manual |
| TFT | Technical Feasibility Testing |
| TJW | Total Jumper Weight |
| TMRR | Technology Maturation Risk Reduction |
| TRADOC | Training and Doctrine |
| TTP | Tactics, Techniques, and Procedures |
| UFR | Unfunded Request |
| UH | Utility Helicopter |
| UON | Urgent Operational Needs |
| US | United States |
| USAAS | United States Army Airborne School |

| | |
|---|---|
| USAIC | United States Army Infantry Center and School |
| USAPHI | United States Army Public Health Institute |
| USASFC | United States Army Special Forces Command |
| USASOC | United States Army Special Operations Command |
| USD AT&L | Under Secretary of Defense Acquisition, Technology, and Logistics |
| VA | Virginia |
| VCSA | Vice Chief of Staff of the Army |
| WWI | World War I |
| WWII | World War II |
| X-MTR | Experimental |
| YPG | Yuma Proving Ground |

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# I. INTRODUCTION

The idea for a personnel parachute can be traced all the way back to Leonardo da Vinci in the 15th century, but not until World War I (WWI) were personnel parachutes used during military operations (Johnson, 1990). Personnel in observation balloons used parachutes as a way of escaping their gas-filled balloons if they caught on fire. German aviators also utilized parachutes to escape their damaged planes (Weeks, 1976). Toward the end of WWI, the United States (U.S.) began developing and fielding their first parachutes to American pilots. In 1918, the commander of the United States Army Air Corps in France, Colonel W. “Billy” Mitchell, introduced the idea of using planes to transport troops over obstacles and inserting them behind enemy lines to overcome the “deadlock of positional war” experienced in WWI with trench warfare (Weeks & Batchelor, 1982). U.S. military leaders did not begin to seriously develop the strategic concept of airborne operations posed by Colonel Mitchell until World War II (WWII). Beginning in 1940, the U.S. Army Air Corps established the Airborne Test Platoon, the 501st Parachute Infantry Battalion (PIB), and modified the Army Air Corps parachute into the first troop parachute known as the T-4 (Weeks, 1976).

Following the modification of the Army Air Corps parachute, the U.S. Military has developed and fielded five troop parachutes; in 2014, the T-11 Advanced Tactical Parachute System (ATPS) became the most recent parachute to be fully fielded to Army Airborne units. Since its fielding, the T-11 ATPS has been the subject of investigation involving the deaths of nine paratroopers, causing several senior military officials to question its safety and design. As a Program of Record (POR), the T-11 ATPS underwent multiple developmental and operational test events. These test events identified six areas of concern, two of which were accepted by the combat developer (U.S. Army Evaluation Center, 2009).

Additional tests and studies were commissioned following the fielding of the ATPS to examine its safety and design in operational use. The results of these tests and studies concluded that the T-11 parachute has a reduced rate of paratrooper jump related injuries that is 43% less than that of the legacy T-10 parachute (Knapik et al., 2014).

Despite the findings of the previous studies and tests, Lieutenant General (LTG) Joseph Anderson (2015), the commanding general (CG) of the XVIII Airborne Corps, authored a memorandum to the Vice Chief of Staff of the Army (VCSA), titled *Request to Assess and Modernize the T-11 Advanced Tactical Parachute System*, which identified seven areas of concern (Table 8). These areas of concern were later modified and prioritized into a list of eight issues (Figure 9) by the Army Airborne Board Joint Working Group (Army Airborne Board, 2016). As the Product Manager Soldier Clothing and Individual Equipment (PdM SCIE) and the Training and Doctrine (TRADOC) Capabilities Manager (TCM), Maneuver Center of Excellence (MCOE), continue to address the concerns of the warfighter and develop future troop parachutes, this report presents an analysis of the options to consider for the program to move forward to meet warfighter and user requirements, while balancing cost and schedule constraints.

## A. PURPOSE OF PROJECT

The purpose of this report is to compare potential acquisition approaches to include incremental upgrade approach, a new design and development approach also known as a single step approach, a non-materiel approach, or a possible combination of these approaches to provide the Army with a recommended path forward for the T-11 ATPS.

## B. RESEARCH QUESTIONS

### 1. Primary Question

What is the best path forward for the U.S. Army's T-11 Advanced Tactical Parachute System (ATPS) to provide the most effective troop parachute system for use in military airborne operations?

### 2. Secondary Questions

1. What are the existing concerns regarding the T-11 ATPS?
2. What capability requirements governed the development, testing, and fielding of the T-11 ATPS?

3. What alternative acquisition approaches are available to address T-11 issues?

4. What are the advantages and disadvantages of various acquisition approaches?

## C. BENEFITS OF THE RESEARCH

The results of this report will inform the Army of the advantages and disadvantages of employing different acquisition approaches when attempting to address warfighter concerns regarding a product, in a post-fielding environment. This report helps develop courses of action to consider, enabling acquisition professionals to choose the best acquisition approach, thus maximizing their program’s efficiency and productivity (Kendall, 2013).

## D. LIMITATIONS OF THE RESEARCH

This research report is limited by the T-11 data received from the PdM SCIE, TRADOC Capabilities Manager (TCM), and the Natick Soldier Research Development and Engineering Center (NSRDEC), and the user and other documentation gathered through public and unclassified online government search engines.

## E. SCOPE OF METHODOLOGY

The scope of methodology for this report consists of three steps: 1) data collection, 2) identification of advantages and disadvantages, and 3) comparative analysis. The first step gathers data from various stakeholders within the airborne community on the T-11 ATPS. Data was obtained through telephone interviews, published articles, manuals, and unpublished documents. The second step identifies the advantages and disadvantages of possible acquisition approaches from each stakeholder’s perspective and the Department of Defense (DOD) Decision Support Systems lens. The final step compares the advantages and disadvantages of each approach in terms of cost, schedule, performance and risk to inform the recommendation.

## F. ORGANIZATION OF THE REPORT

Following the Introduction chapter, Chapter II provides a brief background of Army airborne operations and the evolution of U.S. troop parachutes, with an emphasis on the T-11 ATPS. Chapter III provides a discussion of several studies conducted on parachute-related injuries and identifies the main concerns of the T-11 ATPS stakeholders and what steps have been taken to address them. Chapter IV provides the research methodology, which covers how data is gathered and a description of the analysis tools that are used in the analysis presented in Chapter V. Finally, Chapter VI provides the conclusion, recommendations for a path forward, and areas for further research.

## G. SUMMARY

A product manager's (PdM) goal and responsibility is to provide the warfighter with a materiel solution that meets approved performance requirements, is within budget, and is on schedule, with minimal acceptable risk. Once a product is fielded, the warfighter may discover issues that must be addressed by the PdM, whether those issues are perceived or actual. Providing solutions to these issues post fielding is an extremely difficult task for a PdM to accomplish with the DOD's acquisition framework. Identifying possible solutions and conducting a thorough analysis of those possible solutions that consider each stakeholder's perspective, while adhering to DOD acquisition policy, is essential when determining the path forward for any acquisition program.

# II. BACKGROUND

## A. INTRODUCTION

Arguably the most important piece of equipment in a paratrooper's arsenal is the parachute. Over a short span of 76 years, the troop parachute has advanced tremendously in response to evolving changes in military air transport, airborne concepts, tactics, and procedures. This chapter discusses the history of airborne operations since its inception, along with the progress made in the development of tactical personnel parachutes. Additionally, a thorough background of the current, most advanced, non-steerable tactical troop parachute is presented.

## B. AIRBORNE OPERATIONS

U.S. airborne operations have a relatively short history considering the age of the nation's military. Weeks & Batchelor (1982) described the concept of airborne operations that was first introduced by Col. W. "Billy" Mitchell in 1918. Mitchell suggested that militaries could use multiple aircraft to transport paratroopers around geographic obstacles to an objective behind enemy lines to "overcome the deadlock" of WWI trench warfare (Weeks & Batchelor, 1982). While this concept was born in 1918, its implementation by the United States was another 25 years in the making. Enthralled by Germany's use of paratroopers during the 1930s, along with the beginning of WWII in 1939, the previously discussed airborne operations concept of "vertical envelopment" was reinvigorated (DeVore, 2004). This involved the creation of the all-volunteer Airborne Test Platoon in 1940, and subsequently the 501st Parachute Infantry Battalion (PIB). The United States continued to expand their airborne force despite a lack of doctrine. From 1940 to 1941, the U.S. created regiments followed by divisions. In 1942, the United States established the 82nd and 101st Airborne Divisions (Weeks, 1976).

With the establishment and expansion of the nation's airborne force, the United States War Department published its first doctrinal publication on airborne operations in 1942, called the *Tactics and Technique of Air-Borne Troops* (FM 31–30). This manual became a guide to planners, leaders, and paratroopers within the airborne units. It

described airborne operations as the transport of a small group of troops by aircraft to an objective, in which the paratroopers landed via parachutes to perform any number of missions in austere areas not immediately accessible. This early doctrine also listed several missions of airborne operations, including the following:

- seize and secure terrain until follow on aircraft and troops can reach the area, river and canal crossings, key terrain behind enemy defenses
- establish bridgeheads
- attack defended positions in the enemy’s rear and flank
- seize and destroy lines of communications (LOC)
- vertical envelopment
- act as a diversion to operations of main forces. (United States War Department, 1942)

Limited not only by their objectives, airborne operations were also significantly limited by the availability and type of aircraft provided by the Troop Carrier Command (TCC), weather conditions, and the training level of paratroopers and aircraft pilots. Following the first combat airborne operation in 1942 in North Africa, leaders like Lt. Col. James M. Gavin noticed that for airborne forces to achieve maximum effectiveness, the initial assault must be conducted in mass, in the smallest possible area, within the shortest amount of time possible (Bilstein, 1998). Although the FM 31–30 was published before the airborne force’s first combat airborne operation, it has remained valid in terms of characteristics, limitations, capabilities, and missions performed by paratroopers, with a few exceptions. Current doctrine has been updated to reflect changes in aircraft type, speed and range, increasing weight of equipment carried on the paratrooper, and new missions such as rapid deployment, humanitarian, and special operations (United States Department of the Army, 2015). The new missions noted earlier were required as the operational environment changed toward the end of WWII. Most notable was the implementation of special operations and their use of two new parachuting techniques, high-altitude high-opening (HAHO) and high-altitude low-opening (HALO). First used by the U.S. military in Vietnam in the 1960s, HAHO jumps involve parachutists jumping

from an aircraft at approximately 30,000 feet above ground level (AGL), with oxygen, and then deploying their parachute immediately following their exit. They then maneuver their parachute across miles of terrain to their objective. HALO jumps are the other type of jump used by special operations forces. These jumps require parachutists to jump from a high altitude, with oxygen, then free fall until reaching about 4,000 feet AGL, where they deploy their parachute (Murphy, 2015).

From the initial concept of military airborne operations, U.S. leaders have vigorously debated the cost and effectiveness of airborne operations. While airborne forces experienced a few successful operations during WWII, most of the operations were extremely disappointing, leaving continued doubt in the minds of the decision-makers. Mass-tactical airborne operations are few and far between since WWII, with the latest occurring in 2003 by the 173rd Airborne Brigade in northern Iraq (DeVore, 2004). Most current airborne operations involving personnel airdrops, are conducted by the special operations community, leading many to question the relevance of conventional airborne forces, especially in a time of fiscal constraint and uncertain budgets. Table 1 shows the major combat operations since WWII utilizing mass tactical parachute operations.

Table 1. Mass Tactical Parachute Operations. Adapted from Pike (2013).

| Date | Unit | Operation | Troop Strength | Dropzone | Parachute Type | Country | Type Air Delivery / Notes |
|---|---|---|---|---|---|---|---|
| October 20, 1950 | 2nd Battalion, 187th Airborne Regimental Combat Team (ARCT) | | 1,203 | DZ Easy, Sukchon | T-7 | Korea | Day Mass low-level tactical personnel static-line jump, platform heavy drop gun jeeps, 105mm artillery pieces |
| October 20, 1950 | 1st and 3rd Battalions, 187th Airborne Regimental Combat Team (ARCT) | | 1,470 | DZ William, Sukchon | T-7 | Korea | Day Mass low-level tactical personnel static-line jump, platform heavy drop gun jeeps, 105mm artillery pieces |
| March 23, 1951 | 187th ARCT: 2nd and 3rd Battalions; 674th Airborne Field Artillery Battalion; 2nd and 4th Ranger Companies; Indian army surgical team. | Tomahawk | 3,486 | Munsan-Ni | T-7 | Korea | Day Mass low-level tactical personnel static-line jump, platform heavy drop gun jeeps, 105mm howitzers |
| February 22, 1967 | 173rd Airborne Brigade (Separate): 2nd and 3rd Battalions (Airborne), 503rd Infantry; 3rd Battalion (Airborne), 319th Field Artillery | Junction City | 845 | Katum | T-10 | South Vietnam | Day Mass low-level tactical personnel static-line jump Equipment/supplies air-delivered: Gun MULEs (M274s), 105mm artillery pieces. Jumped at 0900 hours on 22 February 1967. |
| October 25, 1983 | 1st and 2nd Battalions, 75th Infantry Regiment; Det, 618th Engineer Company, 307th Engineer Battalion | Urgent Fury | 500 | Point Salines airfield | T-10 | Grenada | Day mass low-level tactical personnel static-line jump Sgt. Spain and SPC Richardson of the 618th Engineer Company accompanied the Rangers |
| December 20, 1989 | Task Force Red: Elements, 75th Ranger Regiment; Division Ready Brigade, 82nd Airborne Division | Just Cause | 4,000 | Rio Hato east to Fort Cimarron | T-10/MC1 | Panama | Night mass low-level tactical personnel static-line jump at 0100 hours, platform heavy drop LVAD, CDS LVAD Ranger M151 Gun jeeps, HMMWVs, Ammo, Food (MREs), water (CDS). Task Force Red consisted of 1,300 troops and the 82nd Airborne Division's Division Ready Brigade consisted of 2,700 troops |
| December 20, 1989 | Task Force Pacific: Elements, 75th Ranger Regiment; 1st Brigade Task Force, 82nd Airborne Division: 1-504th Infantry; 1-505th Infantry; 2-504th Infantry; C/4-325th Infantry; A/3-505th Infantry; 3-73rd Armor; 82nd Military Police Company (-) | Just Cause | 2,176 | Torrijos-Tocumen Airport | T-10/MC1 | Panama | Night mass low-level tactical personnel static-line jump, platform heavy drop LVAD, CDS LVAD Equipment/supplies air-delivered: M551 Sheridan light tanks, Ranger M151 Gun jeeps, HMMWVs, Ammo, Food (MREs), water (CDS); Elements of the 75th Ranger Regiment jumped at 0124 hours, followed by the 1st Brigade Task Force, 82nd Airborne Division at 0145 hours. Task Force Pacific formed up on the ground by 0411 hours |
| March 26, 2003 | Task Force Viking / Combined Joint Special Operations Task Force - North: Det, 2nd Battalion, 10th Special Forces Group; HHC, 173rd Airborne Brigade; Det, 74th Infantry Platoon; 173rd Support Company, 250th Medical Detachment, D-319th Field Artillery; 501st Support Company; 2-503rd Infantry; 1-508th Infantry; 4th Air Support Operations Squadron; 86th Contingency Response Group | Iraqi Freedom | 954 | Bashur Drop zone | T-10/MC1 | Iraq | Later classified as a combat jump, even though the objective was a coalition-held forward operating airfield. |

## C. MANEUVERABLE AND NON-MANEUVERABLE PARACHUTES

A variety of missions utilize airborne operations to accomplish their objectives. Each mission is unique and requires determining the type and quantity of the force, the parachute drop technique, and the personnel equipment necessary to accomplish the

mission. The changes noted in the previous paragraph led to the development and fielding of different types of parachutes. These parachutes can be placed in two general categories, steerable and non-steerable. Steerable parachutes allow highly trained parachutists to control their descent through toggles. These toggles allow the parachutist to control the direction of travel and turning action of the parachute. Additionally, some round parachute designs provide a steering capability by cutting large holes in the edges of the parachute (Botans, 2014). Special operations missions typically utilize steerable parachutes, using small numbers of specially trained troops to conduct precision air drops where pinpoint landings are mandatory. The U.S. military currently utilizes at least two types of steerable parachutes, the Ram-Air Parachute System (RA-1) and the MC-6 parachutes. The RA-1, as seen in Figure 1, has a rectangular canopy and is used for high-altitude drops allowing the paratrooper to land within a 25–30-meter circle (McGarry, 2013). The RA-1 can be deployed by static line, ripcord or throw out techniques. The reserve parachute system also contains an automatic opening device (AOD) that uses barometric pressure sensors and accelerometers to measure a parachutists' descent rate (Natick, 2002). The AOD deploys the reserve if the device detects that the paratrooper is descending to a certain altitude at a speed higher than the average ROD of the main parachute canopy. The MC-6 is a polyconic shaped parachute that allows a paratrooper to land on drop zones at higher elevations and enables the jumper to back up to correct a landing overshoot (Airborne Systems, 2016).

Figure 1. RA-1 Parachute. Source: McGarry (2013).

Used for mass-tactical parachute operations, steerable and non-steerable parachutes are deployed by a static line. Conventional airborne forces such as the 75th Ranger Regiment, 82nd Airborne Division, and 173rd Airborne Brigade rely on a combination of steerable and non-steerable parachutes to place a large number of paratroopers on a drop zone, massing their forces on an objective, as fast as possible. Parachutists utilizing non-steerable type parachutes cannot maneuver the parachute toward an intended direction; they simply glide in the direction of the wind and use the risers to slip or avoid obstacles. The minimum jump altitude for this type of parachute is approximately 550 feet AGL from a C-130 aircraft and 525 feet from a C-17 aircraft, allowing for the safe opening of the parachute and arrival of the paratrooper on the ground as fast as possible (U.S. Army Developmental Test Command, 2009). There is only one (1) non-steerable parachute in the U.S. Army’s inventory, the T-11 Advanced Tactical Parachute System (ATPS). The T-11’s modified cross/cruciform shape utilizes a slider to control the opening sequence of the canopy, resulting in a decreased opening shock for the paratrooper.

Both the steerable MC-6 and the non-steerable T-11 ATPS consist of three weeks of training at the Basic Airborne Course (BAC) in Fort Benning, GA. During the training,

the students learn proper jump and landing techniques and mass exit concepts that culminate with the conduct of five jumps from a C-17 or C-130 aircraft from 1,250 feet (Maneuver Center of Excellence, 2016a). According to the MCoEs BAC site, these jumps consist of a combination of combat equipment jumps, administrative jumps and at least one night time jump. During a combat equipment jump, the jumpers wear helmet, main and reserve parachutes, Moller ruck sack, a Modular Airborne Weapons Case (MAWC), and carry a dummy weapon (Maneuver Center of Excellence, 2016a). Conversely, a jumper only wears only helmet and the main and reserve parachutes during an administrative jump. Upon completion of the BAC, paratroopers earn an additional skill identifier shown in Table 2.

Table 2. Paratrooper Training. Source: Maneuver Center of Excellence (2016a), Pike (2011b), and United States Army Infantry School (2014).

| Type of Parachute | Type of Training | Length of Training | Additional Skill Identifier (ASI) |
|---|---|---|---|
| T-11/MC-6 | Basic Airborne School | 3 weeks | 5A- Joint Tactical Air Operations |
| | Refresher/ Transition Training | 6 hours | |
| RA-1 | Military Free Fall School | 4 weeks | W8 - Special Forces Military Free Fall Operations |

Training does not stop for paratroopers once they leave the Basic Airborne Course. During the planning and preparation phases of an airborne training exercise or operation, leaders conduct a scrub of paratrooper training records. If a paratrooper has not performed a jump within six months, they are required to undergo a minimum of 6 hours of refresher training (United States Army Infantry School, 2014). The Training Circular for *Static Line Parachuting Techniques and Training* (2014), also states that if the paratrooper is certified on an older parachute, they must conduct transition training that

consists of the same 6 hours of instruction as the refresher training (p. F-1). Additionally, airborne units conduct rehearsals immediately before jumps, providing briefings to paratroopers on the mission, safety and proper procedures for jumping and landing. As a part of the rehearsals, paratroopers demonstrate their understanding of the brief through the conduct of mock door jumps and Parachute Landing Fall (PLF).

A separate school exists for paratroopers utilizing the steerable RA-1 parachute, called the Military Free Fall (MFF) School. Special operations forces (SOF) personnel must complete four weeks of military free fall training at this school in Fort Bragg, NC and YPG, AZ. This specialized training consists of learning about altitude physiology and military free fall techniques, utilizing “mass exits, grouping exercises, night airborne operations and high-altitude airborne procedures in combat equipment and oxygen gear” (Pike, 2011b). Upon completion of the MFF School, paratroopers earn an additional skill identifier shown in Table 2.

## D. EVOLUTION OF PARACHUTES (T-3 THROUGH T-10 PARACHUTE)

The current parachutes in the U.S. inventory have come a long way since the inception of airborne operations. This section provides a discussion of the evolution of parachutes used in military operations leading up to the T-11 ATPS.

Following Mitchell’s introduction of the concept of “vertical envelopment,” the U.S. military began parachute research in 1919 at McCook Airfield with civilian enthusiast and history maker, Leslie Irvin. The initial focus of the research was to design and develop a life-saving parachute for Army Air Corps aviators; the result was the T-3 parachute. The Airborne Test Platoon initially used the T-3 parachute, subsequently modifying it with a static line (Johnson, 1990). With the static line modification, the T-4 parachute was born. The T-4’s design included a three-point harness with an attached back-pack tray containing the parachute and its suspension lines (Batchelor & Weeks, 1982). It also contained a reserve parachute that was loosely connected to the front of the paratrooper to the harness by snap hooks. Primarily used by the Airborne Test Platoon and the 501st PIB in 1940, the T-4 was also utilized in Panama by the 551st PIB in 1943 (Weeks, 1976). Figure 2 shows the T-4 parachute on test platoon soldiers.

Figure 2. Test Platoon with T-4 Parachute. Source: Rigger Depot (n.d.).

As WWII began, the need for modifications to the T-4 became apparent. The first change to the T-4 was the addition of extra webbing and stitching to secure the reserve D rings. Next, a single point quick release box was added. In existence from 1941, the T-5 was the product of the two T-4 modifications mentioned earlier and remained in use until 1945 (Rigger Depot, n.d.). The T-7 parachute began replacing the T-5 in 1944. Designed from the start to be a static line parachute, the T-7 was more comfortable than its predecessor, with an improved reliability. It utilized the same three-point harness as the T-4 and T-5 parachutes, continuing to be a canopy opening first parachute. The T-7, however, had a slower rate of descent (ROD), and its thicker webbing design allowed the paratrooper to carry additional equipment that the T-4 and T-5 did not. The one thing that did not change from the T-3 through T-7 was the shape and size of the main and reserve canopies. Mrozek noted in his book, *82nd Airborne Division* that the T-4 through T-7 parachutes had 28-foot flat circular canopies and 22 to 24-foot diameter reserve parachutes (1997).

The development and design of aircraft throughout WWII by the Air Force created problems for the canopy first opening T-7. Throughout WWII, the Air Force utilized commercial DC-3 airplanes that were hastily modified for the transport of airborne troops, transitioning later to the C-82 followed by the C-119. The C-82 had dual jump doors and a clamshell door in the back for equipment loading, but the C-119 was stronger, more powerful and faster. The Army paratroopers began having problems with

the T-7 when jumping from the faster C-119 due its higher speed. With a canopy first opening design, the paratroopers utilizing the T-7 experienced violent opening shocks, burnt out canopy panels, increased ROD, increased impact force with the ground, and a higher risk of injury (Johnson, 1990). The issues pointed to an incredible number of capability gaps, leading to the development of the T-10 parachute. While no requirements documents for the T-3 through T-10 were found during research, one can infer from the T-10's design, that at least four key requirements for the T-7 replacement were necessary. The first assumed requirement is that the replacement parachute must be interoperable with the faster airplanes; second, it must have a slower ROD; third, the new parachute needs to continue to utilize static line operations; and fourth, it must support the increased weight of the paratrooper and his mission-essential equipment.

Adopted as the standard in 1952 and completely replacing the T-7 by 1954, the canopy-last opening parachute, known as the T-10 is pictured in Figure 3 (Knapik et al., 2014). The T-10's canopy-last opening design addressed the interoperability need by using an opening sequence developed by the British that packed the parachute into not one, but two bags or packs. First, the canopy and lines left the pack as the jumper exited the aircraft. The canopy would then open once the suspension lines were completely deployed, causing the second bag to break open and release the canopy. This opening design allowed the paratrooper to fall below the slip stream of the aircraft before the canopy opened, significantly reducing the opening shock. The T-10 possessed a larger 35-foot diameter inflated parabolic parachute compared to the 28-foot diameter of the T-7. Its size and shape reduced both the number of entanglements and the ROD to 22 feet per second (Johnson, 1990). With a parachute system weight of 44 pounds (lbs.), the T-10 parachute's design supported an average jumper weight including their equipment, also known as the Total Jumper Weight (TJW), of 350 lbs. (Knapik, Graham, Steelman, Colliver, & Jones, 2011). Improving upon the T-7, the T-10's harness had a single release instead of three release snaps, and incorporated canopy release systems on the shoulders that allowed the paratrooper to avoid being dragged on the ground during a windy day (Weeks & Batchelor, 1982). The T-10 experienced several small modifications over its lifespan that included; the addition of an anti-inversion canopy skirt netting, changes to

the canopy skirt pocket length and depth, a color change to foliage green, and a new detachable deployment bag (Mills Manufacturing, 2013a). Each of these modifications was denoted by a letter at the end of the T-10, such as B, C and D.

Figure 3. T-10 Parachute. Source: Weaver (2014).

While the previous parachutes described were non-steerable, one would be remiss if the background did not briefly describe the evolution of steerable parachutes. Utilized toward the end of WWII by the Office of Strategic Services (OSS), the Special Forces, or Green Berets, required special equipment to perform the operations and special warfare tasked to them (Johnson, 1990). Born from Frank Derry's patented design, cutting holes in the outer edges of canopies, the first steerable parachute materialized in 1944 (Gale Research, 1996). The first steerable parachute documented in military airborne operations was the MC1. The MC1's design consisted of a modified T-10 canopy that included several cut-outs creating a gliding effect during the descent. The paratrooper could control the turns through two control lines manipulating the canopy. Documents found, suggest the development date of the MC1 to be post 1952 (T-10 development), and pre-1976 (first Special Forces HALO jump in Vietnam). Modifications to the MC1 began in 1976, mimicking those of the T-10. The most notable changes occurred in the 1988 redesign by the U.S. Army, creating a canopy that opened quickly and had a ROD of four

to five meters per second (Mills Manufacturing, 2013). These modifications provided the paratrooper with increased control over the forward speed. Annotated as the MC1-1C, this redesigned parachute supported a TJW of 360 lbs., had a 360-degree turning time of eight to nine seconds, and a forward thrust of 9.5 miles per hour (Mills Manufacturing, 2013b). The design pictured in Figure 4, however, resulted in paratroopers experiencing violent opening shocks, significant damage to the canopy and an increase in injuries during high-altitude static line jumps (Pike, 2011a). These issues, along with the growing TJW, were significant enough for the United States Army Special Operations Command (USASOC) to develop an Operational Requirements Document (ORD) for a replacement to the MC1-1C, called the Special Operations Forces Tactical Advanced Parachute (SOFTAPS). The SOFTAPS ORD included the following requirements: operator steering ability during descent through a turn and glide capability; reduced opening shock, lower ROD and interoperability with Special Operations aircraft (Pike, 2011c).

Figure 4. MC 1–1C Maneuverable Canopy Parachute.
Source: Kidd (2012).

While USASOC required a replacement for the MC1-1C, the conventional airborne forces also required a replacement for the T-10D (Lucas, 2005). Besides the turn and glide capability, the lower ROD, increased weight capacity and interoperability with

multiple aircraft platforms requirements were a match. The requirements for the SOFTAPS and the T-10’s replacement merged in 2005 into a single ORD titled the Advanced Tactical Parachute System (ATPS) ORD. This ORD combined the acquisition efforts and shared common components such as the reserve parachute, troop harness, the parachute pack tray and the static line. The ATPS ORD described the steerable variant parachute as a pre-planned product improvement (P3I) or Block II of the ATPS program. However, it was determined that the U.S. Army Special Forces Command’s (USASFC) interim solution, known as the SF-10A, met the requirements contained in the ATPS ORD. The SF-10A was subsequently integrated and tested with the ATPS reserve and troop harness, then type classified as the MC-6 parachute system (shown in Figure 5). The MC-6 parachute system consists of a modified polyconic, 28-foot diameter canopy, the T-11R reserve parachute, and the T-11 troop harness. The main capabilities of the MC-6 include a 360-degree turning time of five seconds, improved operational capability at high elevation drop zones with increased reliability and an increased maximum weight capacity of 400 lbs. (Airborne Systems, 2016). While the SF-10A was in use by USASFC since 1999, the MC-6 was fielded in 2006, three years prior to its counterpart, the T-11 ATPS.

Figure 5. MC-6 Maneuverable Canopy Parachute.
Source: Airborne Systems (2016).

Mass tactical jumps, described by Pike (2011a), are battalion or larger sized elements of paratroopers that are dropped from a few to several United States Air Force (USAF) aircraft onto a drop zone or objective. Units conducting mass tactical jumps can utilize either the T-11 non-steerable parachute, the MC-6 maneuverable parachute, or a combination of the parachutes depending on the commander's evaluation of the mission, training and capabilities possessed by the paratroopers under their command and their personal level of acceptable risk. These areas, per the Army *FM 3–99 for Airborne and Air Assault Operations* (2015), is called condition setting (p.1-20). Putting the ability to maneuver a parachute during mass tactical jumps into the hands of inexperienced paratroopers significantly increases the risk of injury to paratroopers. This commander's assessment, coupled with the idea posed by Batchelor & Weeks, that the airborne commander does not want the average military parachutist to do more than what is necessary to operate their parachute (1982) is why the majority of mass tactical parachute operations conducted by conventional forces prefer to utilize non-steerable parachutes such as the T-11 ATPS.

Steerable parachutes have very different designs than that of their counterparts. With that being said, it is possible for them to experience a few similar issues. Looking at the evolution of both types of parachutes can enable combat developers and users to apply lessons learned to the requirements process and tactics, techniques, and procedures (TTP)) of future steerable and non-steerable parachutes.

## E. T-11 ADVANCED TACTICAL PARACHUTE

Over the past 60 years the average weight of the paratrooper and the weight of their equipment has increased as shown in Figure 6. This increase in weight increases the risk of injury during a parachute landing. The increase in risk of injury greatly impacts the survivability of a paratrooper and impacts the airborne commanders' ability to "mass" their forces on an objective. As a result, a requirement for a new parachute capable of supporting the increased Total Jumper Weight (TJW) was developed.


Figure 6. Increasing Weight Capacity. Adapted from Maneuver Center of Excellence (2009).

### 1. Program Summary

The ATPS program is an Acquisition Category (ACAT) III program originating in 1995 from an Operational Requirements Document (ORD) produced by the U.S. Army Infantry Center (USAIC) and approved by the Joint Requirements Oversight Council (JROC), identifying the need for a parachute system capable of supporting an increased TJW of more than 360 lbs. with a lower risk of injury, to replace the T-10 Troop Parachute System (Lucas, 2005). Managed by PdM SCIE, the ATPS was developed in two blocks or increments with an approved Life-Cycle Cost Estimate (LCCE) of $401.59 million to support the research, development, testing, and fielding activities of the system (Sloan, 2009). The ATPS program includes the T-11 non-steerable (Block I), and the MC-6 maneuverable (Block II) canopies, a shared reserve parachute (T-11R) and troop harness (U.S. Army Evaluation Center, 2009).

The T-11 canopy is a static line deployed parachute, designed for mass tactical airborne operations from a minimum drop altitude of 500 feet AGL, from Army and Air Force aircraft travelling at speeds of 150 knots (International Defence Review, 2010). The T-11's modified cross/cruciform shaped canopy, according to the International Defence Review (2010), has an average ROD of 19 feet per second compared to its

predecessors 22 feet per second, while also supporting an increased TJW of up to 400 pounds.

The T-11R reserve parachute, shown in Figure 7, is an aero-conical shaped parachute, designed to open rapidly with minimal collapse and altitude loss post inflation. Mounted on the front of the T-11 troop harness, the T-11R canopy is deployed by the paratrooper using either hand, to pull the activation handle located in the center of the pack. U.S. Army Evaluation Center (2009), noted that the reserve parachute uses a kicker spring to deploy the canopy, preventing the entanglement of the reserve with the main canopy.

Figure 7. T-11R Reserve Parachute. Source: U.S. Army Infantry School (2007).

The T-11 harness was designed to meet the 5th percentile female through the 95th percentile male Soldier (Kalainov, 2000). The harness features shoulder riser attachment points for the T-11 main canopy as well as chest-mounted riser attachment points for the T-11R. Release points are a key characteristic of the troop harness enabling the paratrooper to quickly detach the main canopy. Additionally, the harness features equipment attachment points for items such as weapons cases and an equipment lowering

line, while allowing the quick removal of the harness in case of water landings (U.S. Army Evaluation Center, 2009).

The ATPS program became a Program of Record in 1997, entering the Engineering, Manufacturing and Development (EMD) phase of the acquisition life-cycle, after receiving approval from a Milestone (MS) I, also known as MS B, decision review (Lucas, 2006). The program underwent several requirements updates, according to Lucas presentation on the ATPS history (2006), an initial design validation test failure, a program re-baseline in 2000 and extensive developmental and operational testing from 2001 to 2006. The ATPS provides advanced parachute systems to both conventional and special operations forces that can support a higher TJW, with a decreased ROD, reducing the risk of injury to paratroopers.

Achieving Type Classification (TC) in 2006, the MC-6 ATPS, including the T-11R reserve and T-11 troop harness was fielded to conventional and SOCOM units beginning in April 2006 (Lucas, 2006). Since April 2006, a briefing by Lucas (2006), shows that PdM SCIE has fielded 24,944 MC-6 parachute systems, achieving Full Operational Capability (FOC) in 2013. In 2008, the T-11 ATPS achieved TC and began fielding to the 75th Ranger Regiment in 2009 and achieved FOC in 2014, fielding 43,708 parachute systems to conventional airborne forces (Army Personnel Parachute Update, 2014).

### 2. Requirements

The requirements documents of an acquisition program are a PdM’s guide in designing, developing, testing, and fielding a materiel solution or product. Governed by the Joint Capabilities Integration and Development (JCIDS) process, the development and updating of requirements documents is an iterative process, requiring close coordination between the Combat Developer, the warfighter/user, and the PdM (Chairman of the Joint Chiefs of Staff [CJCS], 2015). Stemming from the results of a study on injuries experienced by Rangers during Operation Just Cause, the Airborne Working Group (AWG) identified a need for a parachute that can support an increased weight capacity exceeding the T-10s current maximum weight capacity of 360 lbs. The

1995 study showed that 4% of the Rangers in 2/75th Ranger Battalion experienced jump related injuries when jumping combat loads that exceeded the maximum weight (Miser, Doukas, & Lillegard, 1995). In response to the need, the Combat Developer USAICS, conducted a Mission Needs Analysis (MNA), also known as a Capabilities Based Assessment (CBA). During the MNA, a Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities and Policy (DOTMLFP-P) analysis was conducted concluding that

> there are no non-Materiel alternatives that will adequately provide or enable the capability to provide Legacy, Special Operations, Interim and Objective Forces with decreased rates of descent or landing impact velocity and impact force given the current weight and weight growth of the Soldier and his equipment. (p. 156)

Additionally, a Cost Operational Effectiveness Analysis (COEA) was performed in 1996 utilizing the Belgian Study to suggest that a reduced ROD would significantly decrease the paratrooper injury rate compared to that of the T-10, thus maintaining combat power, minimizing the logistical burden, and paying for itself due to a 73% reduction in disability and lost work related injuries (United States Training and Doctrine Command, 2005). Subsequently, the ATPS ORD was developed and received approval by the JROC in 1996. This document merged two previous requirements documents, the Advanced Reserve and Harness System (ARHS) and Personnel Airdrop System (PAS) ORDs into one. After several updates to requirements, nine Key Performance Parameters (KPP), shown in Table 3, and 29 Additional Performance Attributes (APA) were established for the ATPS Block I in the CPD (United States Training & Doctrine Command, 2005).

Table 3. Key Performance Parameters for Block I. Source: United States Training & Doctrine Command (2005).

| Key Performance Parameters | Production Threshold (T) | Production Objective (O) |
|---|---|---|
| Net Ready | This capability does not interface with the GIG core enterprise services so as a result there is no NR-KPP nor is supporting architecture products provided. | |
| System Certified on Jump Aircraft | The ATPS must be certifiable on the C-130 and C-17. | Certifiable on all Army, Air Force, Navy, and Marine aircraft currently certified for static line operations. |
| Rate of Descent (Main Canopy) | The rate of descent for the main canopy must not exceed 18 fps with a parachutist weighing 332 pounds including equipment, exclusive of the ATPS. | The rate of descent for the main canopy must not exceed 16 fps with a parachutist weighing 332 pounds including equipment, exclusive of the ATPS. |
| Minimum Operational Altitude (Main Canopy) | The ATPS main canopy will be capable of operations at a minimum altitude of 375 feet above ground level (AGL) (500 feet AGL +/- 125 feet altitude holding error) at 130 - 150 knots indicated airspeed (KIAS) with a parachutist weighing 332 pounds including equipment, exclusive of the ATPS. | |
| Reliability and Maintainability (Main Canopy) | Reliability for the ATPS must be equal to or better than the T-10 parachute system and the maintainability must not exceed 4.8 hours between mean time to repair. | |
| Rate of Descent (Reserve Parachute) | The reserve parachute must consistently stabilize within 250 feet of altitude loss after activation (high speed/total malfunction of main canopy) and achieve a 27-fps average rate of descent during standard day conditions with a parachutist weighing 332 lbs. including equipment, exclusive of the ATPS. | The reserve parachute must consistently stabilize within 250 feet of altitude loss after activation (high speed/total malfunction of main canopy) and achieve a 25 fps average rate of descent during standard day conditions with a parachutist weighing 332 lbs. including equipment, exclusive of the ATPS. |
| Activation Procedures (Reserve Parachute) | A single activation procedure for both total/high speed or partial/low speed main canopy malfunctions. The procedure must take no longer to execute than the current “pull-drop” method and require a pull force of no less than 15 pounds and no more than 22 pounds. | |
| Force Transfer (Harness) | The harness must be designed so that the opening forces of the advanced reserve parachute and the main canopy are transferred along the long axis of the jumper’s body and place the jumper in the proper orientation to execute a proper parachute landing fall under a fully deployed main canopy or when the reserve parachute has been activated. | |
| Reliability (Reserve Parachute) | The advanced reserve parachute must demonstrate a reliability of at least 0.95 under partial malfunctions (low speed or no performance loss malfunctions) and at least 0.99 under a total malfunction (total or high speed malfunction). | |

As mentioned earlier, the ATPS program contains a requirement for a maneuverable parachute. Annotated as Block or Increment II in the ATPS OPD, the ATPS program planned to develop the maneuverable canopy utilizing pre-planned product improvement (P3I). Because of the match in requirements listed in SOCOM's SOFTAPS ORD and the ATPS ORD Block II the two ORDs were merged into one. The five KPPs associated with the steerable canopy are listed in Table 4. Out of the five KPPs listed, the Automatic Activation Device remains as a P3I until technology becomes available.

Table 4. Key Performance Parameters for Block II. Source: United States Training & Doctrine Command (2005).

| Attribute | Production Threshold | Production Objective |
|---|---|---|
| Turning Capability | The MC will be capable of executing a 360-degree turn in a maximum of 7.7 seconds. | The MC will be capable of executing a 360-degree turn in a maximum of 5 seconds. |
| Glide Capability | The MC will have a glide ratio of 1:1. | The MC will have a glide ratio of 1:2. |
| Rate of Descent | The MC will have a landing rate of descent not to exceed 19 fps under standard day conditions at 8,000 feet mean sea level. | The MC will have a landing rate of descent not to exceed 16 fps under standard day conditions at 10,000 feet mean sea level. |
| Automatic Activation | The advanced reserve parachute shall incorporate an Automatic Activation Device (AAD) that will detect failure of the main parachute to deploy and inflate and will automatically activate the reserve parachute in the event of a high-speed malfunction. | |
| Landing | The MC will provide a safe landing on land or in water under standard day conditions in a 13-knot wind maximum steady wind when facing 0 deg oblique to the direction of wind from 0–8,000 ft MSL. | The MC will provide a safe landing on land or in water under standard day conditions in an 18-knot maximum steady wind when facing 45 deg oblique to the direction of wind from 10,000 ft MSL. |

It is important to note the difference between KPPs and APAs. The *Manual for the Operation of the Joint Capabilities Integration and Development System (JCIDS)*, defines KPPs as, "performance attributes of a system considered critical or essential to the development of an effective military capability" (2015). The failure of a product to meet the KPP threshold requirements can result in the need to update and revalidate a KPP threshold value or worse, cancellation of a program. An APA is a performance attribute of a system not considered critical to the mission, or the overall operation of the system, but still important enough to be included in the requirements document (Manual

for the Operation of the Joint Capabilities Integration and Development System (JCIDS), (2015). APAs are often called "nice to haves."

### 3. Testing

Following the validation of the requirements documents, PdM SCIE developed a Test and Evaluation Master Plan (TEMP) to guide the developmental and operational testing of the ATPS. From 1997 to 1999, development and testing of a previously selected T-11 ATPS that utilized "leap-ahead technology" was conducted. After failing to meet critical performance requirements, the contract was terminated, and sources sought was released to industry (Lucas, 2006). Beginning in May 2000, PdM SCIE conducted the first of two "fly-off" tests between seven vendor designs. Down-selecting to two vendors, PdM SCIE conducted a second "fly-off" test in 2001. This resulted in a single contractor being selected, Para-Flite, and development continued into Technical Feasibility Testing (TFT) and four phases of Developmental Testing (DT), spanning three years.

The DT phase I (DTI), described in the *Interim Test Report for Developmental Test of the Advanced Tactical Parachute System* (Tiaden, 2005), consisted of dropping over 600 mannequins from C-130 and C-17 aircraft, between 1,200 feet AGL to 7,500 mean sea level (MSL), from airspeeds ranging from 130 to 150 knots. The weight of the mannequins used ranged between 108 to 332 lbs., representing the 5th percentile female to the 95th percentile male soldiers (Tiaden, 2005). Full and partial malfunctions of the main canopy were conducted during this phase, requiring the reserve parachute to deploy. Tiaden notes that the reserve was also deployed during this phase when no main canopy malfunction occurred, to test the possibility of main and reserve entanglement (2005). Additionally, DTI conducted testing to "quantify trajectory, opening shock, oscillation angle, rates of descent, altitude loss to full inflation, and reliability" (Tiaden, 2005). The canopy and reserve under both partial and complete malfunctions met the reliability requirements in DTI proceeding to DT phase II (DTII) in 2002.

According to Tiaden's report (2005), DTII consisted of 215 live jumps from C-130 and C-17 aircraft. Four issues were discovered during this phase beginning with a

main canopy malfunction requiring the capture of four corner lines into the slider to prevent cross over with other suspension lines and abnormal canopy inflation. The opening of the canopy release unit cover flaps was also an issue requiring attention. The cover flaps on the canopy release unit are a redundant safety feature that safeguards against the inadvertent main canopy release. Third, the reserve belly band came loose on several occasions. It was also noted through user questionnaires, that the canopy control was extremely limited and unpredictable. These four issues were subsequently addressed and required DTI reliability retesting.

DT phase Ib (DTIb) conducted 230 mannequin drops from C-130s in June 2003 (Tiaden, 2005). The exit criteria to move on to DTIIb was an increased reliability of the main canopy and reserve canopy experiencing partial malfunction from .975 and .95 to .99 with a 90% confidence level. Tiaden’s report (2005) noted that the main canopy and reserve met the increased reliability, subsequently proceeding to DTIIb in late 2003.

DT phase IIb (DTIIb) revealed even more issues with the canopy. Conducting 212 live jumps from both C-130 and C-17 aircraft in August 2003, Tiaden’s report (2005) concluded that the canopy was unable to meet the requirements for achieving the ROD, altitude loss, obstacle avoidance, and simultaneous door exit on C-17 requirements (Tiaden, 2005). The requirement ROD was 16 feet per second during steady-state (by 375 feet after exit) during this test. DT results showed that paratroopers weighing under 222 lbs. and jumping from the C-130 were the only group that met this requirement. The altitude loss requirement is described as a parachute deploying, inflating, and stabilizing by 275 feet from exit from the aircraft. The ATPS met this requirement on the C-130 for all weights but failed to meet the requirement on the C-17 when the paratrooper is greater than 300 lbs. During the dual door exit jump testing, where jumpers exited the aircraft with an approximate one second difference from opposite doors on a C-17 aircraft, it was identified that the left door jumper had a slower canopy opening than that of the right door jumper. Additionally, both jumpers involuntarily moved toward the centerline of the aircraft at four seconds after exit, leading to a collision between the two jumpers. Center-lining can be described as the trajectory of the paratrooper after exiting, toward the center line of an aircraft due to the aerodynamics of large aircraft (Tiaden, 2006). Essentially the

airflow surrounding the C-17 pushes paratroopers who are conducting simultaneous exits from opposite doors toward each other.

While the canopy failed to meet the ATPS ORD requirements, the reserve and harness performed well. PdM SCIE was advised to go back to the drawing board and find a new main canopy that could meet ROD threshold of 16 feet per second. After performing market research and establishing a competitive range, PdM SCIE conducted another "fly-off" test between five vendors. From this group of five, two were selected for a subsequent "Fly-off" that addressed glide, oscillation and center-lining (Lucas, 2006). Figure 8 depicts how the PdM conducted its down-select from five to two vendors. The possibility that center-lining would still occur when jumping from a C-17 was identified during this fly-off. Stakeholders participating in the down-select were informed of this possibility during a briefing from PdM SCIE (Neises, 2004). The question of acceptability, if dual door performance could not be met, was posed to the warfighter. While the dual door performance requirement was a show stopper for conventional airborne forces like the XVIII Airborne Corps and 82nd Airborne Division, it was only listed as an APA. PdM SCIE waited for a decision from the user with two options; if the user accepted this possibility, they could continue testing; if they did not accept this the program could be cancelled and go back to technology research and development. The user accepted the possibility and allowed PdM SCIE to proceed with testing.

| Criteria \ Vendor | | Butler | Irvin | Para-Flite | Pioneer | Strong |
|---|---|---|---|---|---|---|
| ROD | Mean | 1 | 3 | 2 | 4 | 5 |
| 18ft/s at 375ft | (95/90) | 5 | 1 | 3 | 2 | 4 |
| Stabilization | Mean | 2 | 5 | 1 | 3 | 4 |
| 27ft/s at 275ft | (95/90) | 3 | 5 | 1 | 2 | 4 |
| Oscillation | < 15 degrees | 4 | 2 | 1 | 3 | 5 |
| Opening Shock | < 10g's | 2 | 1 | 3 | 5 | 4 |
| Canopy Control | sim to T-10 | 4 | 2 | 1 | 3 | 5 |
| | Subtotal | 21 | 19 | 12 | 22 | 31 |
| Dual Door | | 4 | 2 | 5 | 1 | 3 |
| Packing Time | | 1 | 3 | 2 | 5 | 4 |
| Logistics | | 2 | 4 | 5 | 3 | 1 |
| | Grand Total | 28 | 28 | 24 | 31 | 39 |

**SCALE: 1 to 5 (1 being the best)**

Figure 8. PdM SCIE Scoring Criteria for Possible ATPS Main Canopy Solutions. Source: Neises (2004).

Following the second "fly-off," Para-Flite was selected as the vendor to provide the T-11 ATPS canopy. In 2005, the ATPS ORD was updated to reflect a more realistic and attainable ROD, changing it to 18 feet per second (Threshold) and 16 feet per second (Objective). Developmental testing on the Para-Flite canopy began in October 2005 (Lucas, 2006). Testing was conducted on multiple fixed and rotary wing aircraft beginning at 1,200 feet AGL with a minimum jumper weight with equipment of 200 lbs. Completing 190 jumps during testing, data showed that the T-11 canopy was only slightly worse than the T-10D regarding center-lining, and the test community regarded the hazard as the same as the T-10D (Tiaden, 2006). Furthermore, the testing showed that the canopy would not meet the 18 feet per second ROD requirement either. The same report showed that for a 380-lb. jumper, the average ROD achieved during testing was 19.2 feet per second from a C-130 and a 360-lb. jumper averaged a ROD of 19.1 feet per second from a C-17 (2006). Even though testing showed an inability of the canopy to meet the 18 feet per second ROD requirement, the information presented by Tiaden (2006), noted that it was a 2.8 feet per second decrease from that of the T-10D. The Developmental Test Command (DTC) also recommended a minimum altitude for a parachute drop of 550 feet on a C-130 and 525 feet

on a C-17 (Tiaden, 2006). Another issue identified during testing of the T-11 ATPS canopy was corner vent entanglements. During DT phase III (DTIII), while conducting a live dual door jump, the first corner vent canopy entanglement occurred. Concerned about the possibility of future entanglements and wanting to understand the probable frequency and level of injury associated with these types of entanglements, PdM SCIE requested that DTC conduct corner vent entanglement simulations. The results of the simulated corner vent entanglements conducted by DTC, showed that the inherent stability in the T-11 main canopy kept the jumpers adequately separated so that they could perform proper actions upon landing after entanglement with minimal risk of injury. Additionally, the simulated jumpers impacted the ground post entanglement at less than 27 feet per second (Allen, 2011). DTIII was halted in 2006, when a human systems integration (HSI) error was identified. Paratroopers felt the operation of the canopy release assemblies (CRA) was difficult, especially during cold weather situation, resulting in the need to remove cold weather gloves to utilize the canopy releases (Tiaden, 2006). Subsequently, the CRAs were modified, tested and approved by the XVIII Airborne Corps CG.

Beginning in 2007, the T-11 ATPS began Operational Testing (OT). Throughout OT, 3,646 jumps were conducted on C-130, C-17, CASA 212, UH-60, and CH-47 platforms (U.S. Army Evaluation Center, 2009). Testing occurred at three locations: Fort Bragg, NC; Fort Carson, CO; and Fort Wainwright, AK. The OT was conducted in a realistic operational environment, with test paratroopers, jumpmasters, operational jumpers. Multi-ship and single ship air movements and jumps were conducted to test mass tactical parachute operations as well.

During OT, many issues were discovered, but two involved KPPs contained in the ORD. The U.S. Army Evaluation Center (2009), identified the first issue as the minimum jump altitude. The ORD requirement states a minimum jump altitude of 375 feet AGL, while the minimum safe jump altitude identified from a C-130 is 550 feet AGL and 525 feet AGL for the C-17 (U.S. Army Evaluation Center, 2009). Table 5 shows the results of DT on the altitude loss to 27 feet per second velocity.

Table 5. DT Results of Altitude Loss to 27 fps Velocity. Source: U.S. Army Evaluation Center (2009).

| | Weight (lb) | No. of Samples | Mean (FT) | Standard Deviation (FT) | 0.95 Probability, 90% Confidence | Maximum (FT) |
|---|---|---|---|---|---|---|
| C-17 | All Weights | 40 | 280 | 32.4 | 345 | 344.2 |
| | > 300 | 21 | 298.1 | 22.5 | 347.3 | 344.2 |
| | < 300 | 19 | 260 | 30.1 | 327.1 | 325.4 |
| | > 365 | 11 | 302.9 | 24.1 | 363.3 | 344.2 |
| C-130 | All Weights | 38 | 230.6 | 29.2 | 289.7 | 297.2 |
| | > 215 | 31 | 235.1 | 27.7 | 292.4 | 297.2 |
| | > 300 | 12 | 242.5 | 30.7 | 317.5 | 292.7 |
| | > 215 & < 300 | 19 | 230.4 | 25.4 | 286.9 | 297.2 |
| | > 343 | 5 | 232.2 | 27.8 | 326.6 | 258.4 |
| | < 222 | 9 | 213.2 | 27 | 284.6 | 262 |

The second KPP that was not met by the T-11 ATPS, is the ROD threshold of 18 feet per second. The U.S. Army Evaluation Center's report recognized that, while the T-11 ATPS does not meet the KPP (averages 19.1 feet per second), it is a significant decrease from the T-10D (2009). Table 6 shows the comparison between the ATPS and T-10 canopies ROD at steady state.

Table 6. T-11 ATPS and T-10 ROD at Steady State. Source: U.S. Army Evaluation Center (2009).

| Canopy | ATPS | | T-10 | |
|---|---|---|---|---|
| Weight (lb) | Steady State Descent Velocity "mean" (ft/s) | Steady State Descent Velocity "95/90" (ft/s) | Steady State Descent Velocity "mean" (ft/s) | Steady State Descent Velocity "95/90" (ft/s) |
| 380 | 19.2 | 23.9 | | |
| 360 | 19.1 | 22.4 | 21.9 | 28.9 |
| 300 | 17.3 | 21.9 | 20.3 | 25.4 |
| 250 | 15.5 | 20.4 | 18.8 | 24.2 |
| 200 | 14.5 | 17.7 | 17.3 | 21.7 |

Although not a KPP, the size and weight of the T-11 were addressed in OT. When placing 52 paratroopers on a C-130, jumpers stated that the size of the parachute pack

caused them to sit more forward in the seat than they had previously, causing pain in the back of their legs from the pressure of the metal bar on the front of the seat (U.S. Army Evaluation Center, 2009). Compared to the T-10D, the system weight is 9-lbs. heavier at 53-lbs. vs. 44-lbs. (includes reserve parachute). The next issue identified by OT was the pack time of the parachute. The U.S. Army Evaluation Center (2009), reported that the T-11 ATPS had an average pack time of 21 minutes per parachute, four minutes over the ORD APA of 17 minutes per parachute. Evaluators also noted in this report, that as the riggers continued packing the T-11 ATPS, many individuals' pack times decreased, indicating a learning curve effect. The number of collisions and entanglements was also recorded during OT. Ten incidents were recorded out of 3,646 jumps, a 0.0027 probability of occurrence. Only three of the incidents resulted in injuries. Table 7 shows the number and type of incidents experienced during OT (U.S. Army Evaluation Center, 2009). From the maneuverability aspect, testing also recognized that the T-11 ATPS does take longer to maneuver and travel, but paratroopers can avoid obstacles when they are observant and act quickly before the said obstacle.

Table 7. Operational Test Collision/Entanglements Incidents. Source: U.S. Army Evaluation Center (2009).

| TYPE | NUMBER | INJURIES |
|---|---|---|
| Low Altitude Collisions[a] | 3 | 2 Serious[b]<br>1 Minor[c] |
| Corner Vent Entanglements | 5 | 0 |
| Other Entanglements | 2 | 0 |
| Totals | 10 | 3 |

[a]A low altitude collision is the most critical scenario a jumper could encounter regardless of parachute type because the jumper's parachute is unable to re-inflate due to insufficient altitude.
[b]Two injuries occurred as a result of two separate low altitude collisions. One jumper suffered a fractured back to L-1/L-2 (8 Jul 08), and one jumper suffered a stress fracture to his hip (29 Jul 08).
[c]One jumper suffered muscle spasms as a result of a low altitude collision (30 Sep 08).

OT of the T-11 ATPS found the system suitable and effective (U.S. Army Evaluation Center, 2009). While there were KPPs that were not met, the Combat Developer accepted the change to the minimum jump altitude and the increased ROD. Their acceptance is documented in a Department of the Army (DA) G-3/4/7 Memorandum, dated December 16, 2009. Following OT, the program received TC, and subsequently gained a decision approval for Low Rate Initial Production (LRIP) in July 2009. PdM SCIE began fielding the T-11 ATPS in 2009 to the 75th Ranger Regiment, making them the First Unit Equipped (FUE). Since 2009, the T-11 ATPS program has fielded 43,708 parachute systems to conventional airborne forces, phasing out the T-10 parachute in 2014 (Army Personnel Parachute Update, 2014). The program continues to work with the Combat Developer, the user, and other partners to sustain the T-11 ATPS. Since its fielding, the T-11 ATPS has experienced entanglements and T-11R inadvertent activations. The program is currently working with all the stakeholders to address issues they are having and possible solutions to the problems.

## F. SUMMARY

The U.S. airborne forces are arguably considered the spearhead of the Army's force projection. Capable of deploying anywhere in the world at a moment's notice, the United States relies on airborne forces to conduct forcible entry operations to seize or hold an area, enabling follow-on operations against adaptable and unpredictable adversaries (*FM 3–99 Airborne and Air Assault Operations*, 2015). To facilitate these airborne missions a need arose to replace the aging and inadequate T-10 and MC1-1 parachutes. Thus, the Army developed, tested, produced and fielded the T-11 ATPS and MC-6 parachute systems to conventional and special airborne operations forces beginning in 1997 (Lucas, 2006). Developmental and operational testing of the parachutes discovered several inadequacies with the T-11 ATPS when comparing it against the required performance parameters contained in the ORDs. Entanglements, rate of descent, minimum jump altitude, and rigger packing times were a few of these. While the MC-6 began fielding in 2006, it only fulfilled four out of the five Block II KPPs listed in Table 4. The Automatic Activation Device (AAD) remains a P3I for the reserve parachute for the ATPS (United States Training & Doctrine Command, 2005). The T-11

ATPS was fielded beginning in 2009, immediately following acceptance of its limitations, phasing out its predecessor in 2014. Compared to the T-10, the T-11 ATPS is a substantial improvement, even with the inadequacies listed earlier. As the life-cycle manager, it is important for PdM SCIE to continue to work with all the T-11 ATPS stakeholders to identify, address and hopefully fix issues early on.

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# III. LITERATURE REVIEW

## A. INTRODUCTION

This chapter reviews studies that analyzed injuries sustained while executing military airborne operations and identified factors that help define the development of requirements for tactical parachutes. These studies also reviewed the T-10 and T-11 ATPS to provide a comparison of the current and legacy parachute systems. Additionally, the main concerns of the stakeholders within the airborne community, regarding the T-11 ATPS, are identified, and the steps taken to address them are distinguished. This information will help guide the analysis in Chapter V to inform the recommendation.

## B. INJURY STUDIES

The overarching requirement in military airborne operations is to have a parachute that enables personnel to exit from an aircraft and land safely, prepared to fight. A journal article on military parachuting injuries reviewed jumps ranging from 1941 until 1998 and identified the causality of injuries that are still seen in airborne operations today. Increasing wind speed, simultaneous exits, night jumps, equipment carried, height, weight and experience of the paratrooper increase the risk and rate of injuries (Bricknell & Craig, 1999). These factors must be addressed when developing tactical parachute requirements for use in military airborne operations.

Since the initial fielding of the T-11 ATPS, two different studies were conducted by the U.S. Army Public Health Institute (USAPHI) to provide information regarding injuries sustained by Army paratroopers while utilizing the T-11 ATPS. The first study, conducted by Knapik et al., covered a six-month period between March and September 2010, with a purpose of providing "preliminary information on the new T-11 Advanced Tactical Parachute System at the U.S. Army Airborne School (USAAS)" (2011). Observing over 30,755 jumps during this study, the researchers documented only 76 injuries. These 76 injuries were subsequently broken down in the report's findings showing that the T-11 averaged 1.60 injuries per 1,000 jumps, while the T-10 averaged 2.85 injuries per 1,000 jumps; the T-11 achieved 44% lower incidence of injury. Knapik

et al. (2011), attributed the lower incidence of injury of the T-11 ATPS to the increased size of the main canopy. A few downfalls of the larger canopy were noted, such as an increased likelihood of a paratrooper experiencing lateral drift, which increases the probability of a tree landing. Withstanding the increased likelihood of a paratrooper landing in a tree, the 2011 USAPHI study concluded that the injury incidence was lower with the T-11 parachute compared to the T-10 specifically during daytime training jumps without combat loads (Knapik et al., 2011).

The second study, conducted again by the USAPHI, covered a 3.5-year period, from June 2010 through November 2013 (Knapik et al., 2014). The purpose of this second study was to compare the injury rates between the T-10 and the T-11 as during the fielding of the T-11 to the operational Army airborne units. Observing administrative/ non-tactical jumps (jumps without combat loads) and combat loaded jumps (jumps with a weapons case and rucksack) during daytime and nighttime conditions, this study had an increased scope. The researchers also observed multiple operational units that included the 82nd Airborne Division, the XVIII Airborne Corps, and the 18th Air Support Operations Group, increasing the number of jumps observed and analyzed. This same study recorded 1,101 injuries out of 131,747 jumps (Knapik et al., 2014). Out of the 1,101 injuries the T-10 experienced an injury incidence of 9.1 cases per 1,000 jumps, while the rate of injury incidence experienced with the T-11 was 5.2 cases per 1,000. Researchers concluded that the T-11's injury risk was lower compared to that of the T-10 under almost all operational conditions, except for entanglements (1 in 2,816 jumps), making it the safest parachute to jump during training and combat jumps (Knapik et al., 2014).

Although deemed safer than the T-10 parachute, the T-11 ATPS still must mitigate concerns identified within the airborne community. The next section identifies these concerns from the stakeholders' perspective, evaluates the actions taken to address them, and determines the current status of the program.

## C. T-11 ATPS ISSUES/CONCERNS

After observing two phases of DT, an Initial Operational Test & Evaluation (IOT&E) event and at least two different studies on the T-11 ATPS, data from over 166,000 jumps was recorded and analyzed statistically, showing that the T-11 ATPS is much more reliable and significantly decreases the amount of injury incidences than its predecessor, the T-10. The statistics, however, do not make the deaths of nine paratroopers (Table 8) any easier to accept. Investigations into these deaths identified the causes, which ranged from a lack of training, poor exits, and pre-jump inspections for six of the deaths (Product Manager Soldier Clothing and Individual Equipment, 2015). Two other deaths were determined to have been caused by premature activation of a paratrooper’s reserve and debris left in another paratrooper’s parachute, preventing it from properly deploying. The latest death, that of a Mexican paratrooper during a training exercise at Fort Bragg, NC, in 2016 is still under investigation (Jahner, 2016). These fatal T-11 ATPS incidents are a great source of concern to the Airborne community, most notably to the XVIII Airborne Corps.

Table 8. Soldier Deaths. Adapted from Dolasinski (2016) and Product Manager Soldier, Clothing, and Individual Equipment (2015).

| Year | Type of Parachute Used | Location | Type of Training | Root Cause |
|---|---|---|---|---|
| 2010 | T-11 ATPS | Fort Lee, VA | Rigger Student Training | Lack of DZ and surrounding area prep |
| 2011 | T-11 ATPS | Fort Bragg, NC | 82D ABN Training | Improper packing didn't allow parachute to fully inflate |
| 2013 | T-11 ATPS | Fort Stewart, GA | 1/75th Ranger Regiment | High winds |
| 2013 | T-11 ATPS | Fort Benning, GA | Basic Airborne Student Training | Soldier failed to maneuver to avoid other paratrooper |
| 2014 | T-11 ATPS | Fort Bragg, NC | 82nd ABN Training | Improper JPMI |
| 2014 | T-11R with MC-6 | El Centro, CA | Navy Seal | Inadvertent reserve parachute activation |
| 2015 | T-11 ATPS | Fort Bragg, NC | 1/505th 82nd ABN Training | Weak exit |
| 2015 | T-11 ATPS | Fort Polk, LA JRTC | 37th EN, 82nd ABN Training | Poorly secured rucksack struck another soldiers parachute |
| 2016 | T-11 ATPS | Fort Bragg, NC | Mexican Army paratrooper | unknown/under investigation |

LTG Anderson, the CG of the XVIII Airborne Corps, authored a memorandum in 2015 to the Vice Chief of Staff of the Army (VCSA), outlining seven primary concerns

regarding the T-11 ATPS. The concerns identified in this memorandum are shown in Table 9.

Table 9. XVIII Airborne Corps Commander Memorandum.
Source: Anderson (2015).

| |
|---|
| 1. High altitude collisions & entanglements |
| 2. Reduce deployment sequence from 6 to 4 seconds |
| 3. Reduce sensitivity of main curve pin |
| 4. Reduce weight/size of the T-11 to better accommodate paratrooper exiting procedures and reduce paratrooper load |
| 5. Increase paratrooper awareness of a complete or partial malfunction earlier in the T-11 deployment sequence |
| 6. Reduce complexity of parachute packing procedures |
| 7. Ensure rigger force structure is adequate to meet airborne mission requirements |

Many of these issues were identified through XVIII Airborne Corps' lessons learned prompting PdM SCIE, along with members of the airborne community such as the Quartermaster School (QMS), TRADOC Capabilities Manager (TCM) Soldier under the Maneuver Center of Excellence (MCoE), Capabilities Development and Integration Directorate (CDID), and the U.S. Army Natick Soldier Research, Development and Engineering Center's (NSRDEC) Aerial Delivery Directorate (ADD), to work toward finding solutions through either materiel or non-materiel solutions prior to the 2015 memorandum. To formally guide the numerous agencies involved in addressing Army airborne concerns, the Secretary of the Army directed the formation of the Army Airborne Board (AAB), chaired by the CG of the XVIII Airborne Corps (ABC) in January 2016 (Mankel, 2016). To create unity within the airborne community, the AAB officially charged a joint working group (JWG), comprised of subject matter experts (SME), with the responsibility to evaluate and address parachute concerns relating to doctrine, organization, training, materiel, leadership, personnel, facilities, and policy (DOTMLPF-P). Table 10 describes the members of the subgroups within the JWG. Each member of the JWG is considered a stakeholder within the airborne community and for the T-11 ATPS.

Table 10. Army Airborne Board Joint Working Group DOTMLPF-P Subgroups. Adapted from Maneuver Center of Excellence (2016b).

| | |
|---|---|
| Doctrine | Maneuver Center of Excellence (MCoE), Quartermaster School (QMS), 1/507th Parachute Infantry Regiment (PIR) |
| Organization | MCoE, 82nd Airborne Division (ABD), QMS, 1/507th PIR, 4/25 Infantry Division |
| Training | Special Operations Command (SOCOM), 1/507th PIR, 82nd ABD, QMS |
| Materiel | Product Manager Soldier, Clothing, Individual Equipment (PdM SCIE), MCoE, QMS, Army Capabilities Integration Center (ARCIC) |
| Leadership | QMS, 1/507th PIR, XVIII Airborne Corps (ABC), Infantry School Combat Readiness Safety Center (CRSC), QMS, SOCOM |
| Personnel | CRSC, MCoE, XVIII ABC, SOCOM |
| Facilities | 82nd ABD, QMS, 1/507th PIR |
| Policy | Headquarters Department of the Army (HQDA) G4 |

The AAB and JWG gained a consensus on the priorities of the identified concerns based on risks, non-materiel or materiel solutions, and the length of time to develop the solution. Figure 9 illustrates the established priorities of the AAB. A DOTMLPF-P analysis was conducted on each of the areas of concern to determine a path forward for the airborne community and the parachute. Table 11 traces the issues identified by the AAB JWG to applicable requirements within the CPD, through testing, and post fielding.

***Requires Non Materiel solution***

- **(3) - Reducing corner vent entanglement**
- **(6) - Increasing paratrooper awareness of a complete or partial malfunction earlier in the T-11 deployment sequence (first and second points of performance in Sustained Airborne Training)**
- **(8) - Reducing the complexity of parachute packing procedures**

***Requires interim and/or long term materiel solution (changes to the current parachute)***

- **(1) - T-11R inadvertent activations**
- **(2) - T-11 corner crossover inversion**
- **(3) - Reducing corner vent entanglement**
- **(4) - Reducing sensitivity of curve pin**

***Requires full system redesign (new parachute )***

- **(3) - Reducing corner vent entanglement**
- **(5) - Reducing the weight/size of the T-11 to better accommodate paratrooper exiting procedures and reduce paratrooper load**
- **(7) - Reducing the deployment sequence of the parachute from six seconds to four or less**

Figure 9. AAB Established Priorities. Source: Army Airborne Board (2016).

Table 11. Issue Trace Matrix. Adapted from Anderson (2015), Army Airborne Board (2016), Tiaden (2005), United States Army Evaluation Center (2009), United States, Training and Doctrine Command (2005).

| T-11 Issues | CPD Requirement | Developmental Testing (Issue Identified) | Operational Testing (Issue Identified) | Identified in XVIII ABC CG Memorandum | Indentified Priority of AAB JWG | Was it a root cause of a Paratrooper Death? |
|---|---|---|---|---|---|---|
| 1. T-11R Inadvertent Activation | KPP - Reserve Activiation Procedures - Minimum Force Required 15 lbs; Maximum force 22 lbs | Reserve modified and retested | N | N | Y | Y |
| 2. Corner Cross-Over Inversion | N | DTII modified main canopy to capture 4 corner lines into the slider | N | Y | Y | N |
| 3. Corner Vent Entanglement | APA - Maneuverability | DT simulated corner vent entanglements(2007) | 5 occurences in 3,646 jumps 0 injuries <.2%; Considered met | Y | Y | N |
| 4. Main Curve Pin Sensitivity | N | N | Y | Y | Y | N |
| 5. Parachute Weight & Size | APA - System Weight APA $\leq$ 60 pounds | N | System weighs 53lbs w/reserve; noted Paratrooper discomfort from sitting forward in seat; Safety Confirmation recommends maximum 52 pax on C-130 | Y | Y | N |
| 6. Increase Awareness of Partial and Complete Parachute Malfunctions | Equipment Training | N | N | Y | Y | N |
| 7. Reduce Parachute Deployment Sequence | N | N | N | Y | Y | N |
| 8. Reduce Complexity of Parachute Packing Procedures | APA - Packing Time (17 minutes per parachutes) | N | Packing Time APA (17 minutes T actual is 21 minutes) | Y | Y | N |

### 1. T-11 Reserve Parachute Inadvertent Activation

The T-11R or reserve pack tray became a critical issue requiring immediate attention after the death of a Navy SEAL using the MC-6 parachute in 2014 (Steele, 2016). The MC-6 and T-11 parachutes share the same reserve, the T-11R, and troop harness, but utilize very different canopies. A Safety of Use Message (SOUM) was issued following the T-11R incident stating that the possible cause of the reserve was a “loose tuck flap on the jumpmaster’s T-11R ripcord assembly allowed cross-winds to catch under the assembly, which subsequently caused the accidental reserve deployment” (United States Government AMHS 4.0., 2014). A DOTMLPF-P analysis concluded that, although the inadvertent activation of a T-11R is unlikely, the ramifications of an activation could have devastating consequences for a paratrooper. The JWG identified changes to jumpmaster procedures and rigger procedures, and the fielding of a materiel

insert would be an interim solution to inadvertent activations (Army Airborne Board, 2016). The PdM-developed interim solution is depicted in Figure 10. PdM SCIE modified the top and bottom flaps of the T-11R parachutes utilizing the insert without increasing the amount of force required to pull the reserve ripcord. Wind tunnel testing on the interim solution observed no release of the reserve parachute with inserts installed and with winds up to 150 knots. Due to the uncertainty of the long-term effects on the usage of the inserts, PdM SCIE and NSRDEC continue to conduct Design Validation Testing (DVT) on two candidate solutions that modify both the ripcord handle and the T-11R pack tray (Army Airborne Board, 2016).

(L) Shows the inserts and the (R) shows inserts on the original T-11R pack tray.

Figure 10. T-11R Interim Solution Inserts. Source: Bryan (2014).

Interestingly, the possible use of the RA-1 reserve has not been discussed in the AAB JWG. In addition to providing a possible solution T-11R inadvertent activation, it could also fulfill the ATPS Block II AAD KPP requirement. When asked about possible solutions to the T-11R issue, MCoE and PdM SCIE stated that the technology for the AAD, in low altitude jumps, is still being researched and is not available for implementation (J. Yancey, personal communication, December 12, 2016).

### 2. Reduce Corner Vent Crossover Inversion

The corner crossover inversion is a rare but potentially catastrophic malfunction that occurs when the deployment sleeve of the parachute separates from the canopy and materiel in the corner and crosses over to another part of the canopy, creating a bubble-like distortion, disrupting the canopy deployment sequence. The JWG determined that to gain more control over the corner vent panes, efforts are underway to test a retainer band and packing loop tie that will create tension on the suspension lines, as well as working on getting a Modification Work Order (MWO) from TCM Soldier (Army Airborne Board, 2016).

### 3. Reduce Corner Vent Entanglements

During simultaneous mass exit operations with the T-11 ATPS, studies have shown an increased risk in the number of entanglements, with the most common type being a corner vent entanglement as shown in Figure 11. The primary concern with entanglements is that the different weights of the jumpers could cause a heavier jumper to become tangled in a lighter jumper's parachute or suspension lines below them, causing either or both canopies to lose shape or completely deflate. The corner vent entanglement scenario occurred for the first time during DT Phase III, resulting in the need for further testing via simulation by the developmental testing team at Yuma Proving Ground (YPG). The subsequent simulations conducted at YPG showed that while T-11 entanglements can and will occur, the canopies of both jumpers remained inflated after becoming stable at 400 feet of altitude loss; minimal damage to the canopy skirt was experienced but easily repairable; the mannequins maintained 10 - 12 feet of separation during the fall and even when encountering the ground. The testers concluded that the risk of injury with the T-11 ATPS, even during entanglements, was lower than that of its predecessor (Allen, 2011). While the YPG testers intentionally induced these entanglements, two other studies published by the USAPHI in 2011 and 2014 observed that the risk of entanglement was only 0.33 per 1,000 jumps and 0.22 per 1,000 jumps respectively for the T-11 ATPS (Knapik et al., 2011; Knapik et al., 2014). Through an analysis, it was determined that training and rehearsals must stress the importance of

proper exits and the jumpmasters control of paratroopers during their exit to effectively address this issue (Bergmann, 2013a). The AAB, however, directed the PdM to analyze potential materiel solutions to prevent entanglements. Two proposed solutions reviewed were sewing or tacking the vents and adding mesh netting in the corners. Research of these solutions showed, that each one could increase the overall risk to the paratrooper. Corner vents are vital to the performance of the T-11; changing the vents could lead to increased collisions, as well as, increase the size and weight of the system (Army Airborne Board, 2016). PdM recommended closing out mesh netting as a potential solution, but the AAB still wants to review other potential materiel solutions before deciding (Army Airborne Board, 2016).

Figure 11. T-11 Corner Vent Entanglement. Source: Duncan (2016).

#### 4. Reduce Sensitivity of Main Curve Pin

The QMS reported several instances of the main curve pin dislodging, subsequently causing premature opening of the parachute pack trays (Figure 12). The

biggest concern, however, was the possibility that a more catastrophic incident could happen where the misdirection of the curved pin could cause the static line of the parachute to become lodged and disrupt the deployment sequence of the main canopy (Army Airborne Board, 2016). The PdM and the JWG came up with a solution of installing a packing tie that consisted of securing the curved pin to the pack closing loop with a size 3 cotton thread, as seen in Figure 13. The proposed materiel solution was determined to have second and third order impacts to training, parachute packing, and JMPI procedures necessitating testing of the tie. The materiel solution is still under debate while improvements in training and awareness are the interim solution, such as the jumpmaster checking for the correct location and position of the curved pin when performing a Jumpmaster Personnel Inspection (JMPI) and the parachute rigger having a good rotation when storing the T-11 ATPS (Bergmann, 2013b). The AAB wants to review additional solutions and materials for a long-term solution.


Figure 12. Main Curve Pin (#8).
Source: United States Army Jumpmaster School (2014).

Figure 13. Main Curve Pin Safety Tie. Source: Army Airborne Board (2016).

### 5. Reduce Parachute Size and Weight

The pack tray of the T-11 ATPS that holds the main canopy and risers is approximately 20 inches long by 16 inches wide by 14 inches deep and weighs about 38 lb. (U.S. Army Evaluation Center, 2009). The reserve parachute weighs another 14.8 lb., making the T-11 ATPS approximately 53 lb. altogether (United States, Headquarters & Headquarters Company, 1st Battalion, 507th Parachute Infantry Regiment, 2014). The increased size and weight of the T-11 ATPS can negatively impact a paratrooper's exiting procedures which are crucial to the proper deployment of the parachute. During operational testing, it was observed that the size of the pack tray caused paratroopers to sit forward in their seat while in the C-130 aircraft, causing discomfort due to pressure from the metal bar of the seat on their legs (U.S. Army Evaluation Center, 2009). The increased size of the T-11 ATPS along with the additional equipment that airborne units deploy with can dramatically reduce the number of paratroopers that the unit can mass upon their objective. The maximum number of paratroopers transported on a C-130 without pallets is 64. Since the fielding of the T-11 ATPS, the XVIII Airborne Corps units have modified their loading plans on C-130s to have approximately 45 paratroopers due to the size of the T-11 pack trays, as well as the increasing size of other personnel equipment. The DOTMLPF-P analysis concluded that any reduction in weight would

result in a critical design change (Army Airborne Board, 2016). The AAB does not have a current planned solution for this concern.

### 6. Increase Awareness of Parachute Complete or Partial Malfunction

An analysis of complete or partial malfunction of the T-11 determined that these concerns should be addressed through training and leadership to ensure every paratrooper is aware of the different types of malfunctions during the "first and second points of performance in Sustained Airborne Training" (Anderson, 2015). The idea behind this is that, if the first and second points of performance are correctly performed, there will not be a malfunction but if there is a malfunction, the earlier the paratroopers recognize the malfunction, the earlier they can activate their reserve. The two types of malfunctions are known as total and partial malfunctions. A total malfunction is when the parachute fails to inflate, requiring the paratrooper to activate their reserve immediately. A partial malfunction includes any of the following: a semi-inversion, squid, cigarette roll or complete inversion with damage to the canopy or suspension lines, or a sleeve corner vent entanglement (United States Army Jumpmaster School, 2014). Apart from a full or complete inversion, these also require the paratrooper to activate his or her reserve immediately. The U.S. Army Jumpmaster School, *Student study guide* (2014), notes that a strong first point of performance, "proper exit, check body position, and count," can prevent many parachute malfunctions. During this point of performance, the paratroopers must jump out away from the aircraft into a bent forward position with their elbows tight to their sides, knees and feet together, and their hands upon their reserve with their fingers spread apart. Once the aircraft is exited, they are to count by thousands beginning from one thousand to six one thousand. At the end of the count the Student Guide (2014), instructs they enter the second point of performance where they "check canopy and gain canopy control." During this point of performance, they should be on the lookout for any malfunction that may have occurred, that is, looking for any twists, tears, or other items in their canopy that can cause them to fall faster than other jumpers around them. If they determine that they are falling faster they are instructed to pull their reserve (United States Army Jumpmaster School, 2014). Strong initial training, refresher training and rehearsals are proposed to address this issue.

### 7. Reduce Parachute Deployment Sequence

The T-11 system takes six seconds to fully inflate compared to the four seconds of the T-10. Leadership within the XVIII Airborne Corps are concerned that inexperienced paratroopers will "pull their reserve prematurely" because of feeling as though their main canopy was not deploying properly. Testing has shown that the T-11 ATPS has the same lift as the T-10 at four seconds. An analysis determined that this concern should be addressed through training and leadership; focusing on jumper awareness (Maneuver Center of Excellence, 2016b). Per the Assistant Product Manager (APdM) for SCIE, this issue has not been "as hot of an item because it seems the 1/507th PIR has updated their training and we are seeing an increase in jumper awareness" (B. Duncan, personal communication, October 31, 2016).

### 8. Reduce Complexity of Parachute Packing Procedures

As noted in the 2009 Operational Evaluation Report, the complexity of the new T-11 ATPS required more steps and more time for riggers to effectively and safely pack the parachute. The report also showed that as the riggers packed more parachutes the average pack time decreased to the pack time requirement identified in the ORD and CPD (U.S. Army Evaluation Center, 2009). The issue concerning the complexity of the packing procedure is that if it is too complex, then there is a higher risk of incidence from improper packing, as well as requiring an increased force structure in the Rigger MOS to keep up with the parachute packing demand of the airborne units. 1/507th Parachute Infantry Regiment submitted three different packing variations to PdM SCIE. Subsequently PdM SCIE took the different packing variations to YPG and conducted additional mannequin testing to determine the performance of each variation (Schauer, 2016). The most promising variation was the Accordion Fold (AF), but it did not meet the ROD threshold requirements. It was recommended that the PdM pursue this packing variation if the AAB determined it was still needed when the inversion effort was implemented.

## D. SUMMARY

Studies show that the factors that lead to injuries in airborne operations have not changed over the years. The increasing weight of soldiers and the equipment they carry necessitated the requirement to develop a parachute that could lower injury rates and maintain combat power. The development of the T-11 ATPS has decreased the rate of injuries, but the system still has issues that require attention in the form of materiel updates or modifications, a redesign of the canopy or changes to doctrine, training and education or facilities.

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# IV. RESEARCH METHODOLOGY

## A. INTRODUCTION

This chapter provides an explanation on how data was collected for this case and describe the analysis methods utilized in Chapter V that answer the research questions presented in Chapter I.

## B. DATA OVERVIEW

The data obtained in this project covers information about the history of airborne operations, provides an explanation of the different variations of parachutes, and describes the current T-11 ATPS and the issues associated with it. The research includes data gathered through telephonic interviews with: PdM SCIE, Training and Doctrine Capabilities Manager (TCM) Soldier Systems Branch (SSB), Program Executive Office Soldier (PEO Soldier), and Natick Soldier Research, Development, and Engineering Center (NSRDEC) Aerial Delivery Directorate (ADD). The research also includes data extracted from previously published and un-published articles, studies, and other pertinent documentation.

## C. ANALYSIS STRATEGY

Chapter V uses the T-11 issues identified in Chapter III to conduct an analysis of four possible acquisition approaches to inform the recommendation. The acquisition approaches considered in this project are

- *incremental upgrade*: adjustments or modifications are made to any component of the currently fielded T-11 ATPS and the production process is updated with the change for future procurements;
- *new design development*: requires the complete new design of the system or a component of the system to address issue;
- *non-materiel solution*: requires an update to one or more of the following areas: doctrine, organization, training, leadership, personnel, or policy to address an issue;

- *combination approach*: solution requires the uses more than one of the acquisition approaches to address the issue.

The analysis identifies the advantages and disadvantages of each approach from a stakeholder's perspective and the DOD Decision Support System lens of cost, schedule, performance, and risk.

# V. ANALYSIS

## A. INTRODUCTION

This chapter provides an analysis of four acquisition approaches as options to address eleven issues or concerns identified throughout the development, testing, and fielding of the T-11 ATPS. Rate of descent (ROD), minimum jump altitude, and the ability to conduct simultaneous door exits are concerns that were added to the analysis in addition to the eight issues identified by the AAB JWG. Table 12 provides a list of T-11 ATPS issues and concerns that are included as part of the analysis. The advantages and disadvantages of each approach will be reviewed from the stakeholders' perspectives and the DOD Decision Support System lens of cost, schedule, performance and risk to inform the conclusions, recommendations, and suggested areas of further research in Chapter VI.

Table 12. List of T-11 ATPS Issues and Concerns. Adapted from Army Airborne Board (2016) and Tiaden (2005).

| |
|---|
| 1. T-11R Inadvertent Activation |
| 2. Corner Cross-Over Inversion |
| 3. Corner Vent Entanglement |
| 4. Main Curve Pin Sensitivity |
| 5. Parachute Weight & Size |
| 6. Increase Awareness of Partial and Complete Parachute Malfunctions |
| 7. Reduce Parachute Deployment Sequence |
| 8. Reduce Complexity of Parachute Packing Procedures |
| 9. Rate of Descent |
| 10. Minimum Jump Altitude |
| 11. Simultaneous Door Exits |

## B. ANALYSIS CRITERIA

This report analyzes acquisition approaches by evaluating each approach's ability to meet the assigned categories of performance, cost, schedule, and risk criteria, when addressing the 11 issues identified in Table 12. This section defines the criteria for each category and provides the basis for this report's evaluation and analysis of the acquisition approaches. A number score is associated with the category criteria and the ability of an

approach to meet that criteria. An assumption made in this report, is that not all of the acquisition approaches will address all 11 issues; therefore, requiring an evaluation of the approach's ability to meet the criteria for each issue. A category score is then given to each issue in that approach. The average of the individual issue category scores is calculated to obtain an overall category score for the approach. After each category is given a score, the sum of those acquisition categories will be calculated to provide an approach's overall score. This overall score provides the ability to compare the four acquisition approaches against one another. For this report's analysis, a higher overall score is more desirable and infers the most effective approach.

### 1. Performance

The criteria assigned to the performance category is the ability of an approach to address the issues from Table 12. The number of issues that an approach can address determines the score assigned to each approaches performance category. Table 13 depicts the score assigned to the performance category, based on the number of issues an approach can address. The more issues the approach addresses, the higher the score.

Table 13. Performance Scoring Criteria

| Score | Definition |
|---|---|
| 4 | Addresses more than 9 issues |
| 3 | Addresses 6 - 9 issues |
| 2 | Addresses 3 - 5 issues |
| 1 | Addresses less than 3 issues |

### 2. Cost

The cost category criteria are defined by the total cost of an approach (development, testing, procurement, and fielding) for each issue in Table 12 that it can address. In the absence of actual cost data, this report will use an analogous estimate. Each approach may not address all of the issues identified, but a score is recorded based on the total cost of what issues it can address. Table 14 depicts the score assigned to the

cost category, based on an approach's total cost. The lower the overall total cost of an approach, the higher the score.

Table 14. Cost Scoring Criteria

| Score | Definition |
|---|---|
| 4 | Less than $3 Million |
| 3 | $3 Million - $50 Million |
| 2 | $51 Million - $100 Million |
| 1 | Greater than $100 Million |

### 3. Schedule

The schedule category criteria are defined by the total time it takes a solution from an approach to receive a requirements document approval, be developed, tested, and reach FUE. Depending on the approach used, a score is assigned to either each individual issue addressed from Table 12 and then an average is derived for the overall score, or the total amount of time for an approach to address all of the issues possible in Table 12. The scoring criteria for the schedule category is listed in Table 15. The lower the amount of time to field a solution(s), the higher the score.

Table 15. Schedule Scoring Criteria

| Score | Definition |
|---|---|
| 4 | Less than 1 year to field solution |
| 3 | 1 - 2 years to field solution |
| 2 | 3 - 5 years to field solution |
| 1 | Greater than 5 years to field solution |

### 4. Risk

According to the Army Techniques Publication 5–19 *Risk management*, risk is determined by the probability or likelihood an event will occur and the consequence of the event in terms of injury or mission impact (United States, Training and Doctrine Command, 2014). Table 16 defines the levels of likelihood and consequences that are used in this analysis.

Table 16. Risk Assessment Matrix. Adapted from United States, Training and Doctrine Command (2014).

| | | | | | | |
|---|---|---|---|---|---|---|
| Near Certainty: Continuous, regular, or inevitable occurrences | 5 | M | M | H | H | H |
| Highly Probable: Several or numerous occurrences | 4 | L | M | M | H | H |
| Likely: Sporadic or intermittent occurrences | 3 | L | L | M | M | H |
| Unlikely: infrequent occurences | 2 | L | L | L | M | M |
| Negligible: Possible occurrence but not improbable | 1 | L | L | L | L | M |
| **Likelihood** | | 1 | 2 | 3 | 4 | 5 |
| | | Negligible: minimal injury, little or no impact to unit readiness or mission capability | Moderate: Minor injury, illness, degraded unit readiness or mission capability | Serious: Major injury, illness, significantly degraded unit readiness or mission capability | Critical: Loss of limb or eyesight, illness, significantly degraded unit readiness or mission capability | Catastrophic: Death, mission failure, or unit readiness eliminated |
| | | **Consequence** | | | | |

The risk category criteria is defined as the ability of the acquisition approach to reduce the overall risk to the paratrooper compared to the current risk assessed by the AAB JWG in Figure 14.

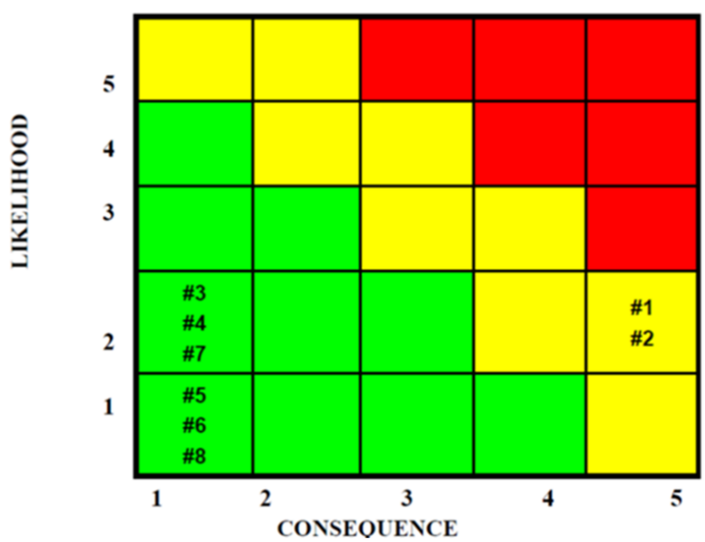


Figure 14. Army Airborne Board Risk Matrix. Source: Army Airborne Board (2016).

The risk scoring criteria is listed in Table 17. If the approach and its solutions reduce the overall risk to a soldier, then it will receive the highest score. Figure 14 provides the baseline risk assessment for the issues identified by the AAB prior to incorporating any acquisition approach and its solutions. Since not all approaches have the ability to address all issues, a score is recorded for each issue addressed by an approach and the potential solution's impact to the current risk assessed in Figure 14. The average of these scores becomes the overall risk category score for an approach.

Table 17. Risk Scoring Criteria

| Score | Definition |
|---|---|
| 3 | Reduces the overall risk to the soldier |
| 2 | No change in the overall risk |
| 1 | Increases the overall risk to the soldier |

## C. ANALYSIS RESULTS

Through the use of scoring criteria assigned to the performance, cost, schedule, and risk categories, Table 18 provides the results of the analysis of the acquisition approaches and their ability to address the issues identified in Table 12.

Table 18. Acquisition Approach Analysis Results

| | Incremental | New Design | Non-Materiel |
|---|---|---|---|
| Performance | 2 | 4 | 3 |
| Cost | 3 | 1 | 4 |
| Schedule | 3 | 1 | 4 |
| Risk | 2 | 2 | 2 |
| Overall Score | **10** | **8** | **13** |

## D. INCREMENTAL UPGRADE APPROACH

### 1. Performance

The Incremental upgrade or modification approach has the ability to address 4 out of the 11 issues identified in Table 12. Due to the number of issues that this approach addresses, this report assessed its performance score as a two on a scale of one to four, with four being the most desirable. The issues addressed by his approach include

- T-11R inadvertent activation
- T-11 corner crossover inversion
- Corner vent entanglements
- Main curve pin sensitivity

Three possible solutions were developed to address the first issue of the T-11R inadvertent activation. The T-11R inserts, the first potential solution, were developed, tested, and fielded as an interim solution to this issue, however, its long-term effects on T-11R operations is unknown. Continued monitoring of the inserts is necessary to gather data in order to determine these impacts, but this solution has the potential become the long-term solution. In the meantime, two potential long-term solutions, a Collapsible Ripcord Grip (CRG) and a new T-11R pack tray effort are currently undergoing testing to assess their ability to address the inadvertent activation issue.

The addition of a tie to the curve pin on the T-11 and MC-6 main canopy closing loops is an interim solution that has been tested and fielded in small numbers and could also become the long-term solution to the main curve pin sensitivity issue. The solutions for the T-11 corner crossover inversion and corner vent entanglements are still undergoing development and testing to assess their ability to address the issues. While possible solutions exist using the incremental approach for these two issues, there is the potential for second and third order effects. For example, the retaining band solution proposed to address the issue of corner crossover inversions may increase the parachute packing complexity. The proposed solutions by the XVIII Airborne Corps CG of covering the corner vents of the parachute with mesh netting or reducing the size of the vents to decrease the likelihood of corner vent entanglements (Army Airborne Board,

2016), may increase the consequence of the entanglement event or negatively impact the overall performance of the parachute.

An advantage of utilizing this approach is that the four top priority issues are able to be addressed. Conversely, a disadvantage to the approach is that seven of the eleven issues identified through testing, the XVIII Airborne Corps CG memorandum and the AAB JWG remain unaddressed. Compared to the three other approaches analyzed in this report, the incremental upgrade or modification approach has the lowest performance score as seen in Table 18.

### 2. Cost

The cost of the incremental upgrade or approach was determined through the use of a combination of given program estimates and analogous cost estimate for the individual solutions to the issues in Table 12. The cost of those individual issue solutions is then summed up into a total approach cost, that includes engineering support, design validation, materials for testing, developmental and operational testing, procurement, and fielding costs.

Table 19 shows the costs for the solutions for the individual issues addressed with an incremental approach along with the total cost of the approach to address the identified issues in the performance section of this approach (Product Manager Soldier, Clothing, and Individual Equipment, 2016). With an approach, total cost of $30,047,000, the incremental approach is assigned a score of 3. The advantage of this approach, is that the total cost estimate is less than the new design approach and all of the combination approaches.

Table 19. Incremental Cost Category Scoring. Adapted from Product Manager Soldier, Clothing, and Individual Equipment (2016).

| Issue | Solution | Cost for the Solution | Total Issue Cost | Cost Score for Issue |
|---|---|---|---|---|
| 1. T-11R Inadvertent Activation | a. T-11R inserts | $180,000 | $2,161,000 | 4 |
| | b. CRG | 1,981,000 | | |
| 2. T-11 Corner Crossover Inversion | Retaining band | $1,013,000 | $1,013,000 | 4 |
| 3. T-11 Corner Vent Entanglement | a. mesh netting | $26,213,000 | $26,213,000 | 3 |
| 4. Main Curve Pin Sensitivity | Safety tie | $660,000 | $660,000 | 4 |
| | Total Approach Cost | | $30,047,000 | 3 |

The disadvantage of this approach is that the cost estimate for the corner vent entanglement issue is an analogous estimate based on the T-11R CRG effort with significantly more complexity. The cost for procurement was derived from a rebuy year's parachutes, of 4,200 parachutes multiplied by the average cost per parachute, $5,757 (Maneuver Center of Excellence, 2009). The T-11R insert solution has already been completed but no information was obtained regarding the cost of this effort. Therefore, an analogous estimate was utilized for this solution as well. The total amount for this effort could be more or less than the analogous estimate provided in this report. Another disadvantage of this approach is that the solutions being pursued now may not work, requiring additional design, development, testing and procurement efforts, thus increasing the cost to an unknown amount. With a cost estimate of $30M, the incremental approach only has the ability to address four of eleven issues. This must be considered when looking at the advantage of an incremental approach versus a new design approach.

### 3. Schedule

This section analyzes the incremental upgrade or modification approach's time it takes for potential solutions to the four issues to be fielded to the first unit. Because this approach involves the concurrent development, testing and implementation of the four potential solutions each issue has an assigned schedule category score. The average of the four issues' category scores is then taken to achieve an overall approach schedule

category score. The four issues that are possible for this approach to address have schedules that vary from 7 months to 4 years. Table 20 displays the individual issues' estimated schedule, its associated schedule category score, and the overall schedule category score for the incremental upgrade or modification approach. This approach's overall schedule category score was assessed as a 3.

Because these potential solutions are currently undergoing testing, and in the case of the T-11R inserts and main curve pin safety tie, are already fielded in small numbers the time it takes for these potential solutions to be implemented is much shorter than a new design. This approach also has the opportunity to address future issues as they arise. A disadvantage of this approach is that for each potential solution the Product Manager must get a Modification Work Order (MWO) or an approved Materiel Change Proposal (MCP) from the MCoE to obtain funding and begin the development of these solutions. This process can take anywhere from 30 days to one year depending on the assigned priority. Another disadvantage of this approach is that combat developers and PdMs must walk a fine line between a modification and upgrading the parachute system so much that it become a completely different system. The level of the modification to the design may also impact this approaches ability to field a potential solution quickly, requiring extensive testing. This is the case with the CRG solution for the T-11R inadvertent activation as seen in Table 20. This solution, according to the MCP submitted by PM SCIE (2016), requires four different test events. Additionally, if testing of these possible solutions uncovers second and third order effects, additional development, design, and test efforts must then take place, subsequently, increasing the schedule.

Table 20. Incremental Schedule Scoring. Adapted from Product Manager Soldier, Clothing, and Individual Equipment (2016).

| Issue | Solution | Time to FUE | Schedue Category Score |
|---|---|---|---|
| 1. T-11R Inadvertent Activation | a. T-11R inserts | 2 years 8 months | 3 |
| | b. CRG | | |
| 2. T-11 Corner Crossover Inversion | Retaining band | 1 year 4 months | 3 |
| 3. T-11 Corner Vent Entanglement | Mesh Netting | est. 4-5 years | 2 |
| 4. Main Curve Pin Sensitivity | Safety tie | 7 months | 4 |
| | | Overall Category Score | 3 |

### 4. Risk

The overall risk category score for the incremental approach was assessed at a 2. Each potential solution to the four issues that an incremental approach could address, was evaluated and assigned a risk category score based on its impact to the overall risk of the T-11 ATPS. The risk category score for each of the four issues was added together then averaged to find the overall approach risk category score. Table 21 shows how the potential solutions for each issue could potentially impact the likelihood, consequence, and overall risk to the ATPS.

Table 21. Incremental Approach Risk Calculation. Adapted from Army Airborne Board (2016).

| Issue | Current Risk Assigned | Potential Solution Impact | Risk Category Score |
|---|---|---|---|
| | Likelihood (L)/ Consequence (C )/ Overall (O) | ↑ ↓ No Change (NC) to L, C, O | |
| 1. T-11R Inadvertent Activation | (L) 2 / (C ) 5 | ↓(L), NC (C ), NC (O) | 2 |
| 2. T-11 Corner Crossover Inversion | (L) 2 / (C ) 5 | ↓(L), NC (C ), NC (O) | 2 |
| 3. T-11 Corner Vent Entanglement | (L) 2 / (C ) 1 | NC (L), ↑ (C ), NC (O) | 2 |
| 4. Main Curve Pin Sensitivity | (L) 2 / (C ) 1 | ↓ (L), NC (C ), NC (O) | 2 |
| Overall Risk Category | | | 2 |

When conducting the analysis of the risk for the incremental approach, this report found that while the implementation of a solution may decrease the likelihood of an event occurring, it did not change the consequence. Because of the low ratings of likelihood, if the consequence does not decrease then the overall risk will not change. Risk assessments are very subjective based on opinions, perceptions, and interpretations. Because the T-11R inadvertent activation has been associated with the death of a paratrooper, the consequence was determined to be catastrophic for this issue. Discussion could be made about the level of this consequence, and the fact that it does not take into consideration many other contributing factors such as rare gale force winds, possible faulty reserve packing, or a possible lack of protection of the ripcord grip. The same debate can be had for the level of consequence assigned to the corner crossover inversion issue. While this malfunction can occur, the paratrooper has a reserve that can be activated in this case. Additionally, the corner crossover inversion is very rare, meaning the probability is lower than the AAB assessment of infrequent (2016). While conducting research, no deaths were found to be related to crossover inversions, bringing up the question of, what is the actual severity of the occurrence? The only change to consequence that we found was the possible increase in consequence of the corner vent entanglement issue if the mesh

netting were to be implemented. This change in consequence to serious, did not change the overall risk of the ATPS.

## E. NEW DESIGN DEVELOPMENT APPROACH

### 1. Performance

The new design approach has the ability to address 10 out of the 11 issues identified in Table 12. Simultaneous exit is the only issue that this approach cannot address due to systemic center-lining issues with jumping out of high speed aircrafts. The performance score assessed to this approach in this analysis is four. With a new design approach the warfighter has the advantage of using all of their lessons learned to ensure that the requirements accurately reflect their needs and possible trade-offs.

By starting with a Materiel Development Decision (MDD), a new design program would benefit from a thorough Analysis of Alternatives (AoA). An AoA can examine the possible use and/or adaptation of several existing parachute technologies. For example, looking at the use of the MC-6 for conventional forces, as there have been no known deaths associated with this steerable, static-line deployed parachute. Another possible solution that exists but needs more development for mass tactical airborne operations includes the reserve utilized with the RA-1 containing an Automatic Activation Device (AAD). While the AAD is included as a P3I for the current T-11 ATPS, the technology for its use on low-altitude low opening (LALO) jumps is not currently available and requires additional science and technology (S&T) development (J. Yancey, personal communication, December 12, 2016).

When looking at the new design approach it is important to understand why the T-11 ATPS began in the first place, to reduce the ROD that ultimately reduces the number and severity of jump related injuries. The materiel needed for a lightweight parachute with a large enough diameter to reduce the ROD enough to decrease jump related injuries requires additional S&T development. By satisfying all but one of the issues, a new design approach has a distinct advantage of being tied as the highest scoring approach with the combination approach regarding its ability to address the issues.

Disadvantages of the new design approach include the lack of technology maturity for an available solution to many of the issues identified by the airborne community. While a new design approach can have the advantage of being able to conduct research and development to mature technologies for the solutions, the disadvantage of is that the technology may not become mature enough for use in a new parachute design for mass tactical airborne operations. Trade-offs also include cost and time to develop the solution necessary to satisfy the requirement. Regardless of the type or design of the parachute, paratroopers will always experience a center-lining effect when conducting simultaneous door exits, especially from a C-17 (Tiaden, 2006).

Lastly, while addressing all but one of the issues identified in Table 12 will satisfy the warfighter, the prospect of beginning a new parachute program to replace the T-11 ATPS two years after reaching FOC may not be an acceptable approach to Congress impacting the availability of funding for a new design approach

### 2. Cost

The T-11 ATPS effort for a new canopy, reserve and troop harness had a LCCE of approximately $401.59M (Sloane, 2009). For the new design approach, this report utilizes the T-11 ATPS as an analogous estimate, thereby assigning it a cost category score of 1. While this approach is substantially costlier than both the incremental and non-materiel approaches, it has the potential to address all but one issue identified by testing, the XVIII Airborne Corps Commander and the AAB JWG. Another advantage is that performance of the parachute system is the driver for a new design approach. While the cost of an approach should be subject to affordability, the airborne community is able to get requirements and funding approved due to their ability to sell the need for the capability. A disadvantage of this approach is that the T-11 ATPS utilized commercially available parachutes, while a newly designed parachute would require extensive research and development of technology to accomplish its goal of addressing 10 of 11 issues identified in Table 12. This means that the costs to achieve this goal could be considerably more than the current estimate, potentially rendering it unaffordable. Finally, in order to receive funding for this approach, a new design program must

compete against other high profile programs, whose capability is seen as useful and effective in recent combat operations versus training exercises.

### 3. Schedule

Utilizing an analogous approach to assess the time it will take for a new design approach to begin fielding, this report identified a minimum of 10 years to FUE for this approach based on the T-11 ATPS program. The requirements process alone took the ATPS program 2 years to get approved and continued to evolve until 2005. The T-11 ATPS program conducted several fly-offs while looking at commercially available systems starting in 2000. The program achieved FUE in 2009 after 10 years. The estimate of 10 years for a new design approach equates to a schedule category score of 1, which is the longest of the four acquisition approaches. The advantage of a new design approaches longer schedule is the ability to conduct research and development to mature technology, versus rushing potential solutions into the integration of a design and having to go back and fix issues.

A disadvantage of this approach is that the requirements must be solidified before beginning the engineering, manufacturing, and design phase of a program. If the requirements continue to change then the cost and schedule associated with incorporating those requirements into an approved design increases exponentially. Additionally, this approach does not allow the XVIII Airborne Commander’s high priority issues identified to be addressed until the requirements process is complete which can take 2–5 years in itself.

### 4. Risk

When looking at the 11 issues, 6 have the potential to be eliminated with a new design approach. The issues that could be eliminated through the use of this approach include: corner vent entanglement, main curve pin sensitivity, parachute weight and size, deployment sequence reduction, ROD, and minimum jump altitude. While the corner vent entanglement issues may be eliminated, the risk of entanglements remains. Despite this approach’s ability to address all 11 issues and potentially eliminate 6, it does not reduce the ATPS’ overall risk associated with the remaining issues. This is simply

because a new design cannot reduce the consequence associated with a T-11R inadvertent activation or a crossover inversion malfunction. Therefore, the new design approach is assigned a risk category score of 2.

## F. NON-MATERIEL APPROACH

### 1. Performance

A non-materiel approach has the ability to address 9 out of the 11 issues identified in Table 12. This report identified this approaches performance score as a three. This approach utilizes the three main areas of doctrine, training and education, and leadership to address the following nine issues:

- T-11R inadvertent activation
- T-11 corner crossover inversion
- T-11 corner vent entanglement
- Main curve pin sensitivity
- Awareness of partial and complete malfunctions
- Reduce parachute deployment sequence
- Reduce complexity of parachute packing procedures
- Rate of Descent
- Simultaneous door exits

Following the death of a Navy Seal utilizing the MC-6 parachute and T-11R in 2014, the issue of the inadvertent activation of the T-11R became the number one priority of the XVIII Airborne command. Despite this unfortunate incident, a change in doctrine and training of reserve packing checks, jumpmaster inspections, and paratrooper reserve handling awareness are capable of addressing this issue. The issue of corner cross-over inversions is also able to be addressed through the update of doctrine and training for rigger parachute packing procedures. Another advantage of this approach is the ability to address corner vent entanglements without changing the performance of the T-11 ATPS. Through the modification of exit procedures and the early identification of obstacles in airborne training, corner vent entanglements can be addressed, but not eliminated. The

main curve pin sensitivity can also be addressed through doctrine and training for riggers; rotating parachutes in the pack sheds, training and inspection emphasis for jumpmasters on the correct location of the curved pin. The only way that the issue of awareness of partial and complete malfunctions can be addressed is through the training of the paratroopers beginning in the basic airborne course and continuing this training during rehearsals and refresher training. This issue also includes the effort of leadership to reduce the negative stigma associated with activating or pulling the reserve parachute. PdM SCIE and NSRDEC conducted studies and found that the T-11 ATPS actually has the same amount of lift at 4 seconds as the T-10 parachute (Duncan, 2016). Paratrooper training and awareness of this fact, along with experience will instill confidence in the T-11 ATPS. Currently, the PdM along with the QMS are testing different types of folding techniques that attempt to address the issue of reducing the complexity of parachute packing procedures. While this issue was identified during OT with the average packing time of 21 minutes versus the APA requirement of 17 minutes, the learning curve indicated that the average pack time would decrease (U.S. Army Evaluation Center, 2009). Another advantage of this approach is the ability of doctrine to set a maximum weight limit on combat equipment carried on the paratrooper to address the ROD issue. While the T-11 ATPS ROD KPP threshold of 18 fps was not met by the 95th percentile male, its average ROD of 19.1 fps was accepted by the XVIII Airborne Corps and the combat developer following OT in 2008. Lastly, the XVIII Airborne Corps has the ability to change their TTPs regarding simultaneous exits to reduce the impact of center-lining to parachute entanglements and collisions.

Other advantages of utilizing a non-materiel approach to address these nine issues includes a shorter amount of time to implementation and a reduced sticker price. This approach allows different users to tailor their doctrine, training, and TTPs to meet their mission. A disadvantage of the non-materiel approach is the inability of this approach to address the two issues of reduce parachute size and weight and minimum jump altitude. Disadvantages such as the persistent perception of many paratroopers (leaders and privates) that materiel solutions are the only adequate way to address parachute issues and an unwillingness of the leadership to significantly modify doctrine and TTPs to

address simultaneous exits and ROD issues also exist. Finally, the most notable disadvantage of a non-materiel approach is that even with the change in doctrine, education and training, and leadership, human error can still play a significant role in the performance of the parachute due to their ability to make decisions/choices despite the implementation of these items

### 2. Cost

The costs of the non-materiel approach's ability to address the issues listed in Table 12, were inconsequential when compared to the three other approaches. The update of training manuals and points of instruction at the BAC, refresher training, and rehearsals was estimated at approximately $10,000 per issue addressed. This amount is an analogous estimate from PdM SCIE's *Materiel change proposal* (2016), estimating the update to technical drawings for the corner vent crossover inversion issue. With the non-materiel approach addressing 9 out of 11 issues, multiplied by $10,000 per issue, the overall non-materiel approach cost is approximately $90,000. This estimate corresponds to the cost category score of 4. As the least expensive approach compared to the other three, the costs associated with the non-materiel approach can be further reduced if the doctrine, training and education, and leadership changes are implemented together versus separately. Because BAC, refresher training, and rehearsals are continuous efforts with available funding, it is difficult to determine if the true cost of these updates.

### 3. Schedule

Modification or updates to training and technical manuals, POIs, or TTPs requires approximately 6 months to 1 year to complete which is the least amount of time to implementation when compared to the other approaches. With the non-materiel approach's ability to reach implementation within 1 year, a score of four was assessed to this approach's schedule category. One of the key advantages regarding an approaches schedule to implementation, is that it is normally a routine action, wherein lessons learned are applied and documented on a regular basis. Secondly, the issues that are able to be addressed utilizing this approach can be addressed utilizing training, rehearsals and other means that already exist.

A major disadvantage of this approach is that personnel who update the manuals, POIs or TTPs must receive approval from the Training and Doctrine Command (TRADOC), when it impacts conventional forces within the military. Depending on the supporting personnel at this command, the approval process of these changes can increase the amount of time to this approach's ability to get to implementation. Another disadvantage of this approach is that the implementation of the doctrine, training and education, and leadership may not fully address an issue listed in Table 12. This requires additional efforts to address the issues, ultimately increasing the schedule.

#### 4. Risk

No matter how much doctrine, training, education and leadership is applied to address the 11 issues in Table 12, the risks associated with these issues and the overall risk of the T-11 ATPS remain the same. The risk category score of 2 is given to the non-materiel approach, as a result. A thought to ponder is the ability of training to change the perception or interpretation of the level of consequence associated with these issues. This possible variable means that the overall risk of the T-11 ATPS and the 11 issues could increase or decrease.

# VI. CONCLUSIONS, RECOMMENDATIONS AND AREAS FOR FURTHER RESEARCH

## A. CONCLUSION

The overall scoring of the four different approaches suggests that the non-materiel approach addresses the most number of issues, in the shortest amount of time, and with the lowest cost. Additionally, scoring showed that a new design approach can address a majority of the issues but it will take a significant amount of time and money before a solution is delivered. The incremental upgrade approach provides the ability to address higher priority issues with a technologically available, materiel solution in a shorter period of time and at a reduced cost compared to a new design. Qualitative information obtained through this report differs from the quantitative results, pointing to a combination of the approaches as potentially the most appropriate. Ultimately, leaders must assign weights to the different categories of performance, cost, schedule, and risk to account for the tradeoffs that they are willing to accept.

Four possible combinations of the approaches exist, with each having its own advantages and disadvantages. Tables 22 and 23 show the cost and schedule estimates for the possible combination approaches. The estimated costs in Table 22 were calculated by combining the total cost of each approach within the combination. The analogous schedule estimates in Table 23 show the potential timeframes for each combination approach. Solutions to issues would be fielded within these timeframes.

Table 22. Acquisition Approach Combination Costs. Adapted from Product Manager Soldier, Clothing, and Individual Equipment (2016) and Sloane (2009).

| Combination | Estimated Cost |
|---|---|
| Incremental/New Design | $431.637M |
| Incremental/Non-Materiel | $30.137M |
| New Design/Non-Materiel | $401.68M |
| All Three Approaches | $431.72M |

Table 23. Acquisition Approach Combination Schedules

| Combination | Schedule Estimates |
|---|---|
| Incremental/New Design | 5-10 years |
| Incremental/ Non-Materiel | 1-3 years |
| New Design/Non-Materiel | 5-10 years |
| All Three Approaches | 5-10 years |

The first combination of approaches, incremental and new design, addresses all but two of the issues using a materiel solution; they are increasing the awareness of partial and complete malfunctions and simultaneous door exits. This approach would satisfy the XVIII Airborne Corps' intent of finding solutions to their top priorities as soon as the technological solution is available, while continuing to develop the requirements documents and technology necessary to address the remaining issues. Another advantage of this approach is that the interim solutions developed from an incremental approach could be utilized in the new design, with the recommendation by the AoA. The disadvantage of this approach is that it requires a significant amount of money and depending on the issue, time, to address the applicable issues.

The second combination of incremental and non-materiel approaches only addresses 9 out of the 11 issues; leaving the minimum jump altitude and parachute size and weight issues remaining. This combination approach is currently being pursued by the PdM, XVIII Airborne Corps, and Combat Developer to provide both short-term and long term solutions to the issues while maintaining the positive features of the T-11 ATPS. The advantage of this approach is that it provides both materiel and non-materiel solutions to issues at the lowest cost, and in the shortest amount of time among the possible combinations. This approach also allows the airborne community to continue to utilize the T-11 ATPS, while gaining experience, familiarity, and possibly more confidence in the system that was already developed and fielded.

Combining the new design and non-materiel approaches addresses all of the 11 issues in Table 12 by providing a short-term solution utilizing the non-materiel approach and a long-term materiel solution through a new design approach. This combination allows the required technology to develop and mature, to meet a new design's validated

requirements. The disadvantage of this approach is that it does not meet the XVIII Airborne Corps' intent of implementing possible materiel solutions as fast as possible for the top priority issues. Another disadvantage of this approach is that it does not address the minimum jump altitude and size and weight issues. These issues may not be showstoppers for the airborne community due to the T-11 ATPS meeting the weight KPP and receiving formal acceptance of the higher minimum jump altitude by the user. Additionally, the size and weight of a parachute may not be as critical due to the lack of recent airborne operations covering long distances.

A combination of all three approaches, could be the best approach when addressing all of the issues in Table 12. Possibly providing a near-term solution addressing the issues through doctrine, training, education, and leadership; a mid-term materiel solution for the four top priority concerns of the XVIII Airborne Corps and the AAB JW; a long-term materiel solution pursuing the development of the science and technology needed to address many other issues listed in Table 12 but not addressed by the incremental approach. The scope of the incremental and new design approaches can be tailored to meet cost and schedule boundaries set by the AAB. This combination addresses all of the stakeholder concerns. The disadvantage of this approach is the potential for the cost and schedule to grow without boundaries being set. Another disadvantage is that the leadership within the XVIII Airborne Corps and the AAB may change and the priorities assigned to the issues that should drive the level of effort in each of these combinations may be required to change.

An important item discovered during the research for this report is that there is no surprise regarding the risk associated with Airborne operations; however, our society and culture make even the slightest bit of risk intolerable. Leaders can mitigate most of the risk through the proper use of doctrine, training, education, and leadership. This report found that no one approach will completely reduce or eliminate the overall risk of airborne operations, unless the perceptions of the consequences change. The current perception is that the issues faced by the airborne community are due to the parachute and its supporting equipment, even though data from many different studies and investigations suggest otherwise. The death of a paratrooper makes leaders, families, and

society question a pure non-materiel approach, because of the question: What more could have been done to prevent this tragedy? This leads the DOD down a path of a materiel approach, despite the analysis showing that it does not resolve or lower the overall risk of the ATPS.

## B. RECOMMENDATIONS

The objective of the research report was to provide options for a path forward for the U.S. Army's T-11 Advanced Tactical Parachute System (ATPS). To provide the most effective troop parachute system for use in military airborne operations a combination of all three acquisition approaches is recommended. A near-term, mid-term, and long-term strategy for implementing the approaches should be used to address all of the issues identified in Table 12. As part of a near-term strategy, the airborne community should immediately incorporate lessons learned into doctrine, training, education, and leadership to mitigate several risks until potential materiel solutions are developed and fielded. Secondly, the solutions that have been developed, tested, and fielded in small quantities through the incremental approach, such as the T-11R inserts and main curve pin tie, should be fielded to the rest of the airborne units, as soon as possible, under a MWO. As a part of the mid-term strategy, these modifications should then be monitored for potential second and third order effects to airborne operations. Additionally, test and evaluation activities should continue to assess the effectiveness of solutions such as the T-11R CRG, pack tray, retaining band. These potential modifications would be designated as the T-11A. Additionally, it is recommended that the T-11 corner vent entanglement issue be closed out under the mid-term strategy and included as a part of the long-term strategy developing the requirements for a T-11B. Following the development and validation of the requirements, it is recommended that the use of the MC-6 in mass tactical airborne operations and the RA-1 reserve parachute be considered during a thorough AoA. Concurrently, research and development should be conducted to mature science and technology regarding lightweight parachute material and the use of an AAD for low-altitude low-opening jumps. In order to pursue these strategies, it is imperative to establish a priority of effort and resources, with money and personnel being allocated to the development of parachute along with conducting research and

development of solutions for the higher risk issues. Figure 15 provides an example parallel schedule for the near, mid, and long-term efforts.

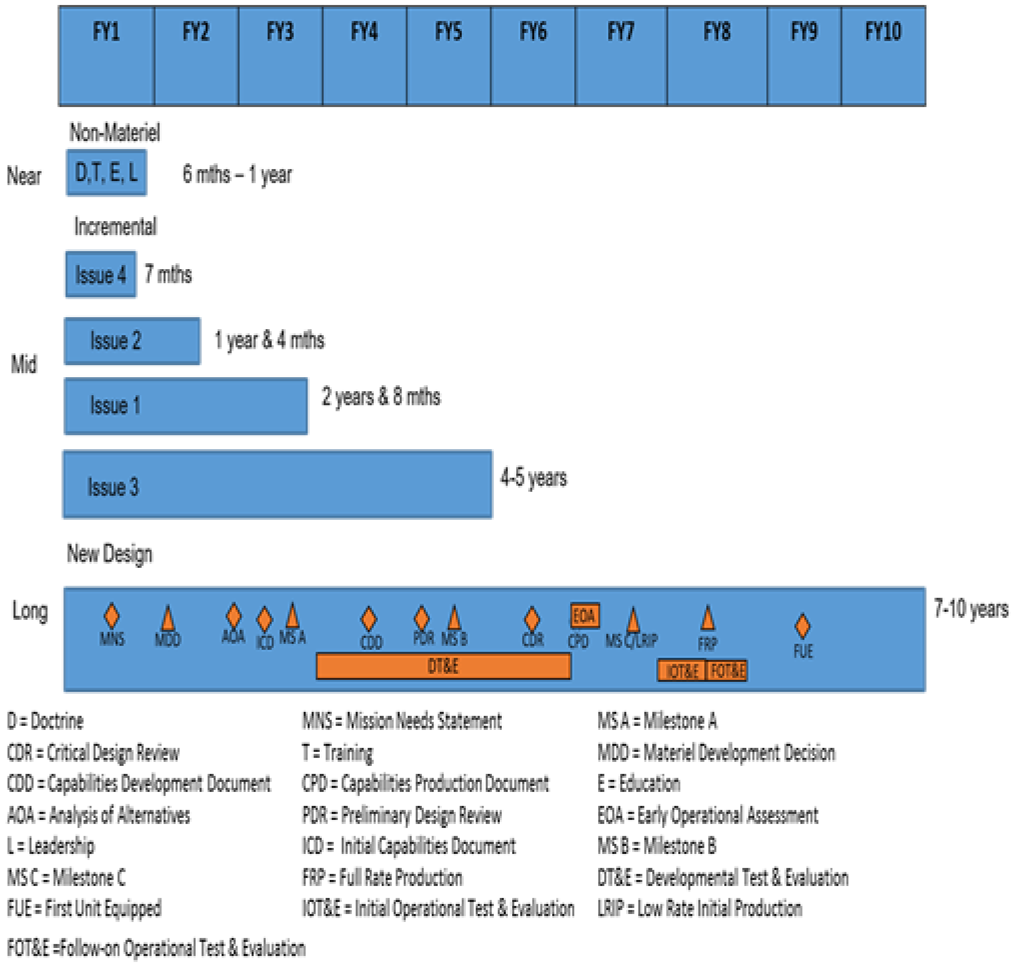


Figure 15. Example Parallel Approach Schedule. Adapted from Product Manager Soldier, Clothing, and Individual Equipment (2016).

## C. AREAS FOR FURTHER RESEARCH

### 1. Conduct CBA on T-11 ATPS Acquisition Approaches

The report conducted a qualitative analysis on the T-11 ATPS by identifying the advantages and disadvantages of each acquisition approach option. A formal cost benefit analysis would serve to validate or show the lack of cost effectiveness when addressing issues.

### 2. Use of Mass Tactical Jumps in Today's Military Operations

Based on the results of the research, it was identified that there is a considerable amount of time and resources spent on the development of equipment and training for airborne operations. As history shows, the Army's use of tactical parachutes during mass tactical combat airborne operations has declined since WWII. Research should be conducted to determine if the use of mass tactical parachute operations is still relevant in today's military operating environment; given its inherently risky nature, in a risk adverse society.

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